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THIRD SERIES.

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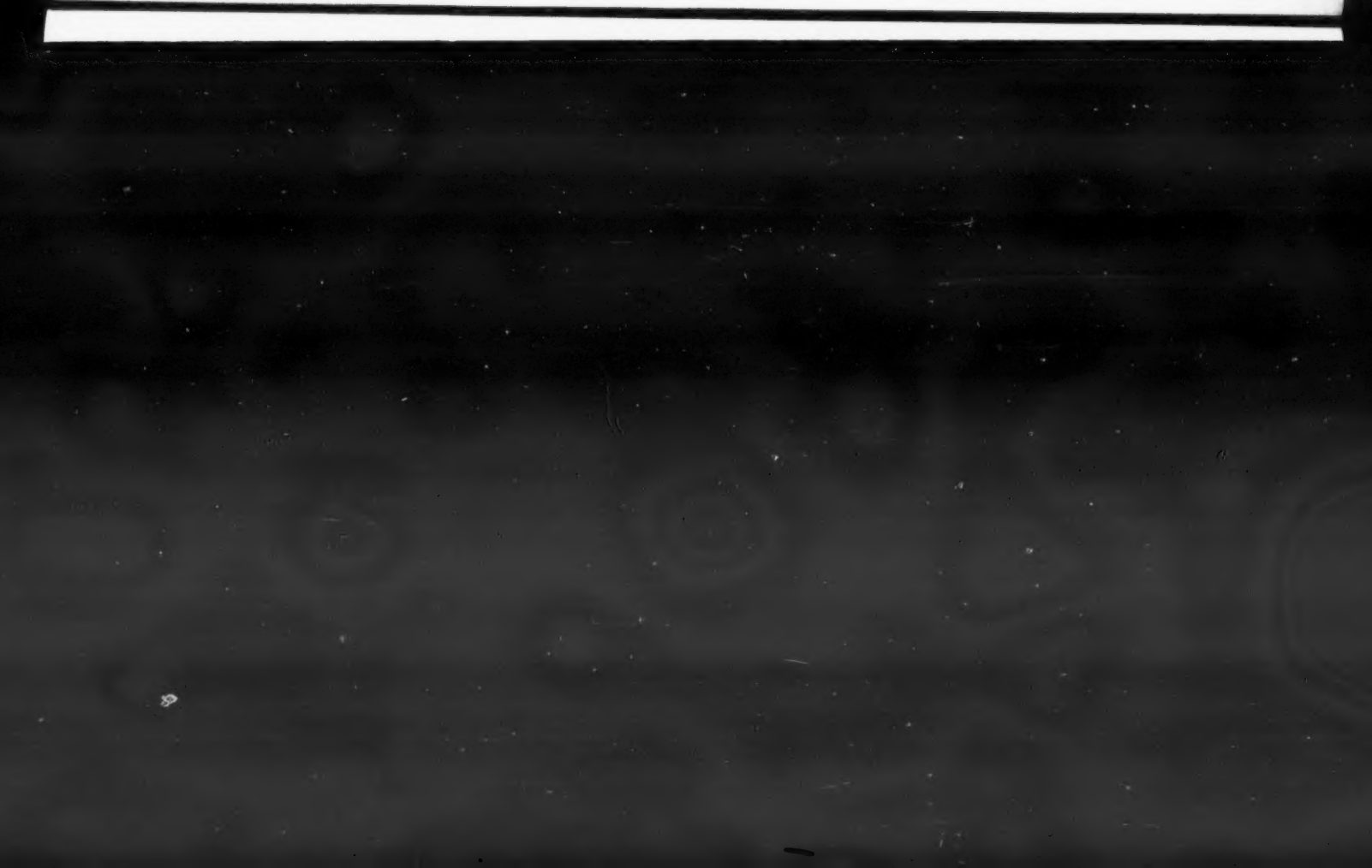


THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. I.—*Spiral Goniometry in its Relation to the Measurement of Activity;* by CARL BARUS.

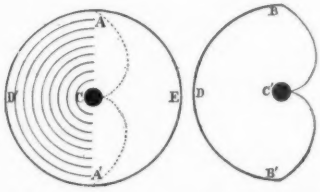
1. *Preliminary.* — Under this cumbersome title* I shall refer to the art of measuring variable angles between two coaxially rotating bodies by the displacement of a set of semicircles terminating in the same diameter in one body, relative to a set of spirals in the other; or by equivalent systems of spiral and straight edge. Problems which may be reduced to a measurement of the angular magnitude in question are of frequent occurrence in practical physics, and in most instances a moderate degree of accuracy will suffice because the quantity to be measured itself fluctuates within certain limits. As it is such cases which I have chiefly in mind, I will first give an account of the method in various stages of development, and then proceed with the more obvious applications to the evaluation of activity and speed.

2. *Dial and Index.*—In fig. 1, AA' is a circular disc (to be called the *dial* in this paper) capable of revolving around an axis passing normally through its center. On this disc a series of concentric, equidistant semicircles are inscribed, in such a way that the locus of their ends is the diameter AA'. BB' is a plate (to be called the *index*) bounded on one side of a diameter by the semicircle BDB', of the same radius as the dial,

* The instrument for measuring plane angles is the circular protractor; but the word "protraction" is not available. On the other hand the word goniometer like goniometry has been made to refer to solid angles like those between faces of a crystal. As I have no such purpose in view I use the above caption with misgiving and merely to express an operation which would consistently be called "circular protraction" in rotating bodies.

and on the other side by two symmetric confluent spirals BC' and $B'C'$. The plate BB' when in position, is placed immediately in front of AA' as shown by the dotted lines on the dial, and is capable of revolving normally around the same axis C independently of AA'. Since the curves BC' and $B'C'$ are by definition such that equal angular increments (in degrees of arc, say) correspond to equal radial increments (in millimeters, say) the number of ends of the semicircles visible beyond the spiral edge of BB' is numerically identical with the angular displacement of AA' relative to BB', reckoned

1.



from the fiducial position (no circles visible) given in the diagram, fig. 1. Now if the system AA', BB' revolves as a whole, the ends of the semicircles will tend to appear like complete circles, and this more fully in proportion as the speed is greater. It is therefore merely necessary to count the number of visible circles from the circumference inward, in order to measure the angle between AA', and BB', no matter whether the rotation be right-handed or left-handed, nor what its speed may be. Two spirals BC' and $B'C'$ have been provided in order to admit of changes in the sign of rotation.

The maximum angle measurable in this way is clearly greater than 90°, and clearly less than 180° in this simple contrivance (cf. § 4); for if the spirals be symmetrically prolonged in the directions $C'B$ and $C'B'$, and if the partial circles instead of terminating in a semicircle be similarly contained in a sector, the measurable angle will increase until the sector vanishes.

If $d\varphi$ be an angular increment and dr the corresponding radial increment of the spiral, then

$$dr \propto d\varphi,$$

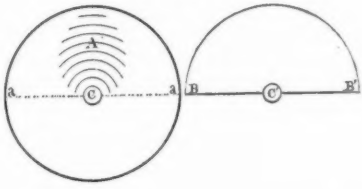
and therefore the method is equally sensitive at all parts of the angular field, though perhaps the central parts are more fully controlled by the eye. The error in reading is in the most unfavorable case equal to the angular value of the distance between two consecutive semicircles on the dial, increased by the angular value of an arc, which is just visible on rotation. The latter quantity depends on the sharpness with which the

semicircles stand out from the dial (§ 6). It is therefore expedient to tax the eyes in the smallest degree possible by using a *dull black* index and also a dull black dial, on which the semicircles are inscribed with white paint. I have availed myself of the black cardboard much used by photographers, upon which the circular lines could be inscribed with a ruling pen* by suitably thinning "flake white" or "Chemnitz white" with turpentine. In larger practice such dials could be printed on card board from a copper plate.

To guide the eye it is of course necessary to accentuate consecutive 5° and 10° circles in the usual way. Moreover a fixed narrow radial scale, containing the running numbers of each of the successive intervals of 10°, and placed directly in front of the whirling system of dial and index, further facilitates the reading. Indeed it is now quite as clear as an ordinary scale.

3. Instead of the arrangement given in figure 1, it is obviously admissible to allow the semicircles of the dial to terminate in spirals while the counting edge of the index is a diameter. If carried out in the plan of figure 1, however, such a goniometer if adapted to measure positive angles would not at once be available for negative angles seeing that a rotation of the index 180° around its diameter is necessary for this purpose. An auxiliary adjustment of this kind would, as a rule, be objectionable in practice; and therefore the design *A*, figure 2, in which the locus of the edges of the partial circles

2.



of the dials are symmetrically intersecting spirals, is preferable. The index in this case is the blank semicircle BB', and its initial position on the dial is shown by the dotted line aa. C' is a small circle used for attachment.

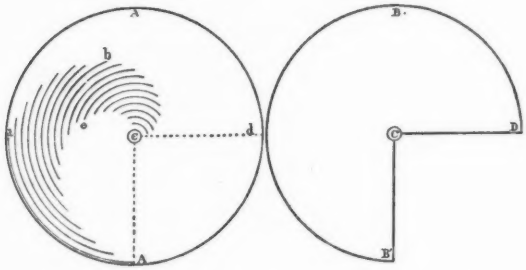
Remarks similar to those of § 2 may be made with reference to the measurement of angles greater than 90°. In this case the counting edges of the index BB' are to be made the bounding radii of a sector and the spiral loci of A are to be

* The convenience of a ruling pen for such purposes was pointed out to me by Prof. F. H. Bigelow.

prolonged and rotated in opposite directions until their initial radii subtend the same angle as the sector of the index. The limiting case is again reached when the sector vanishes. The reading is here made from the center outward. If however in figure 1, the area AEA' had been filled with concentric circles and the area $AD'A'$ left blank, the readings for both positive and negative angles would be made from the circumference inward. It is in the direction of further progress to obtain two such readings simultaneously.

4. *Repetition.*—In figure 3 the spirals terminating the ends of the partial circles on the dial are no longer symmetric, but

3.



are so circumstanced that one spiral may be brought into coincidence with the other by rotating it about the center a stated number of degrees. In such a case if the reading of positive angles be from without inward, the reading of negative angles will be from the center outward. It is clear also that angles of any magnitude may be read by proportionately increasing the size of the dial. The same result may, however, be reached within a reasonably small area of dial by methods of repetition such as the following; and these methods are particularly appropriate for the present purposes, because they incidentally afford the means for reducing the error of reading to the smallest possible value. §6.

In figure 3 let the spirals be 90° apart, and let each admit of a direct reading (as above shown) between 0° and 180°. Conformably with this arrangement let the index BB' be a full circle with a right-angled sector $B'C'D$ cut out of it. The initial position of the sector on the dial is indicated by the dotted lines $A'Cd$. If therefore the index rotates on the dial counter-clockwise, the measurement is made in virtue of the spiral Cba, and the partial circles will gradually *emerge* from behind the index until with 180°, the ends of all are visible. On further rotation the circles beginning with the innermost

will commence to *recede* behind the second limb of the index, until with 360° the last has disappeared, and the initial position of dial and index recurs. The procedure is therefore capable of indefinite repetition, all the readings being made from the center outward.

Similar remarks apply for clockwise rotation of the index on the dial, except that the reading now begins at the circumference.

6. *Eccentricity.*—Retaining the same dial, if an index of smaller angular opening were used, there would often be two readings simultaneously in view in different parts of the field, at an angular distance apart equal to the given angle of the open sector. Thus with a single sector of 60° there are two readings between 150° and 180° of the forward radius corresponding to 90° to 120° of the rearward radius, supposing the index to be twisted counter-clockwise. Repetition is necessarily interrupted for measurement must cease at 330° of the forward radius of the sector. The latter condition could easily be met by choosing a larger dial so that the spirals would sweep over an angle greater than 180°. But as increased size is not a desideratum, the end in view may be gained more satisfactorily by cutting two diametrically opposite sectors of 60° each, out of the index. In such a case there are always two readings in the field.

Leaving the ulterior advantages gained by this method to be considered in the next paragraph, I will here point out that the result obtained as a mean of the two simultaneous readings in question is essentially more nearly correct. For let the rotation of the index be as above: then at the advance radius of the sector, the reading will generally fall short of the true angle, seeing that the ends of the partial circles here emerge from behind the index; whereas at the other radius of the sector the reading will generally be in excess of the true angle, for here the partial circles recede behind the index. In all cases however *the latter reading will be as much in excess of the true angle as the former falls short of it*, and therefore the mean value will be free from systematic error (eccentricity as it may be called) to less than one-half of the angular value of the distance between two consecutive partial circles—in the most unfavorable case. It is thus that two readings virtually double the efficient size of the dial caet. par., or double the number of concentric circles.

Furthermore, if by reason of close graduation, or of indistinct demarcation, or the like, the projecting ends of a number of consecutive partial circles escape detection in case of a spinning dial, it is clear that the first of the visible circles will be symmetrically located on each side of the true angle. Even if

certain of the circles on either side of the true angle are too faint to be visible, therefore, the error of a double reading need be no larger than has been pointed out above. For instance in a dial in which consecutive radial millimeters were each marked by a partial circle of 60°, in such a way that a millimeter corresponded to a degree of arc, the reading was made by an index containing open sectors of 30°. The following results were obtained:

First reading, a	17	27	37	47	58	68, etc., millimeters.
Second reading, $a+30°$	51	62	72	82	92	101, etc., millimeters.
Difference	34	35	35	35	34	33. etc., millimeters.
$\frac{1}{2}(2a+30)-15°$	19·0°	29 0°	39·5°	49·5°	60·0°	69·5°, etc.
True angle	20°	30°	40°	50°	60°	70°

In these cases the attempt was made to increase the angle in successive steps of 10° each by special adjustment, as shown in the last line. The angle found as the mean of the two readings does not differ from the true angle by more than a degree, part of which is referable to the preliminary adjustment as well as to actual irregularities of graduation. In spite of this good result it is seen that the differences (third row) of corresponding readings (first and second row) is in excess of the angle of the index (30°) by 3° to 5°. This shows, therefore, that when the system is spinning around, the projecting ends of about two circles on each side of the circle corresponding to the true angle, are so short as to escape detection.

6. *Multiple spirals.*—Although the preceding paragraph indicates that faintness of graduation does not necessarily vitiate the method, it is desirable to have the marks come out as early as possible. This end, together with all the suggestions of the preceding paragraph may be promoted at once, and even in a relatively *small* dial as follows: A smaller angular distance between the paired spirals is chosen and the advantages of continuous double reading and of repetition are secured by employing more than two open sectors on the index. In this case if the design is judiciously constructed as many systems of paired spirals may be traced out on the dial as there are open sectors on the index, the whole representing a set of equidistant whorls. If therefore when both dial and index are spinning around together, the protruding end of one of the partial circles which just escapes detection in the above designs is a, visibility has now been increased to the extent that a/n just escapes detection, where n is the number of sectors.

A good arrangement of this kind is shown in figure 4, in which the dial AA' contains three sets of paired spirals subtending arcs of 60° each, with a blank space of 60° between consecutive pairs. The index is shown at BB' and has three

equidistant sectors of 30° each cut out of it, and its initial position on the dial AA' is indicated by dotted lines. All the spirals are produced until 120° of arc are swept over, and if a radial millimeter is to correspond to a degree, the effective

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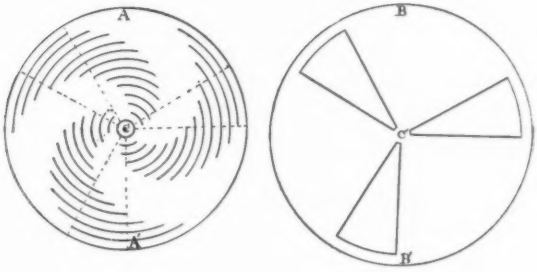


radius of the dial will be 120 millimeters added to the radius of the small internal circle of attachment, C. For practical reasons the diameter may be made somewhat larger than this in order that the removed sectors may appear as windows in the index plate.

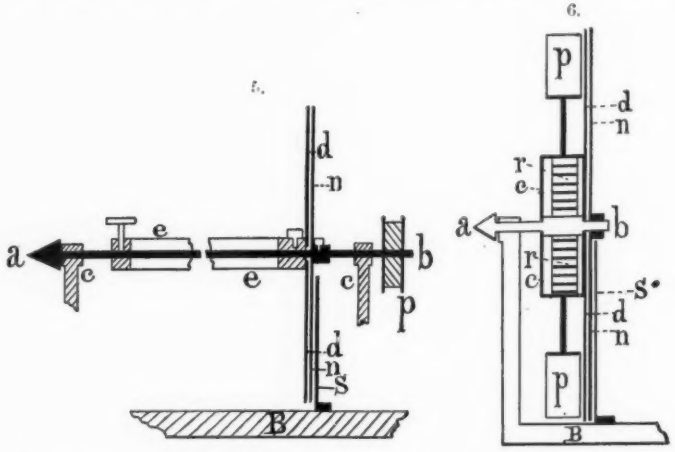
Obviously all the sectors move over corresponding spirals in like manner, and hence the visibility of the protruding end of any partial circle is not only increased threefold but errors in drawing are reduced in value, no matter how fast the system may spin around its center. Again there are always two readings in view, one for the emergence of the front edge of the spiral band and the other for the recession of the rear edge. These angles (a) are 30° apart and from their mean value $\frac{1}{2}(a+(a+30))-15$, the eccentric error mentioned is the preceding paragraph has been eliminated. Other systems are easily devised.

7. *Measurement of activity.*—The present method of goniometry is peculiarly applicable to problems in which the quantity to be measured fluctuates about a mean value to a degree greater than the error of reading discussed above. Such is usually the case with the rate at which a motor works. In approaching this problem from the mechanical side, physicists have usually preferred to find the angular speed at which a measurable twist on the shaft is maintained, chiefly perhaps because the method is capable of great refinement, as for instance in Rowland's* researches on the mechanical equivalent of heat.

* Rowland: Proc. Am. Acad., xv, p. 157, 1880.

This is the method to which the above simple designs are tributary, and the diagram of an apparatus for measuring the work put out by a shaft in a given time is given in figure 5, in longitudinal section.

Let *ab* be a long rod whose torsion coefficient is of known suitable magnitude, and suppose the end *a* to be put in connection with the shaft of the motor and the end *b* with a tachometer or revolution counter, and let *cc* be the journals in which this rod revolves. The rod is concentrically surrounded throughout the greater part of its length by the stiff tube *ee*, one end of which may be rigidly joined to the rod near *a* by a set screw. The other end of the tube with the attached dial *dd* is capable of revolving around the rod in virtue of a journal, unless resisted by the set screw in question. Supposing the latter fixed and the shaft revolving, twist may be imparted to the rod by means of the friction pulley *p*, and its amount measured by the index *nn* fixed to the rod immediately in front of the dial *dd*, in the manner shown in the above paragraphs. *S* is the stationary scale with numerals to facilitate the reading, and it is attached to the base *B* together with the journals *c*, *c*. When no friction is applied at *p* the rod *ab* and tube *ee* spin around together in such a way that no angular deviation between index *nn* and dial *dd* is registered. When a suitable frictional resistance is applied, the index will be dis-



placed in angle relative to the dial, by an amount proportional to the frictional resistance. The efficient part of the torsion rod is clearly the length within the tube, and if by a preliminary calibration the intensity of the torsion couple per degree

of displacement of index and dial is known, the moment of torsion for any observed displacement is given at once. This quantity multiplied by the angular speed is the activity sought. Thus if the number of revolutions is n per minute, the angular speed will be $\omega = 2\pi n/60$; and if the moment of torsion m be expressed in kilogram-meters

$$\omega m / 75$$

is the activity required in horse powers.

The calibration may be made once for all by twisting the rod *ab* in place by a known couple, and noting the corresponding deflection on the dial. Radial holes may be left in the pulley *p* for this purpose, in which spokes of known length are inserted. From the hookshaped ends of these, given weights are suspended so that if m' be the moment of the couple per degree of deflection at the dial and δ any observed deflection, $m = m' \delta$. To fix the ideas suppose a steel rod $0{\cdot}4^{cm}$ in diameter and 50^{cm} in efficient length were chosen: then one degree of deflection at 1000 revolutions per minute would correspond to about ·01 horse power.

8. *Tachometer.*—The construction of the speed indicator is easily inferred from the preceding paragraph. As shown by the diagram figure 6, *ab* is a short rod capable of revolving in a journal fixed to the bed plate *B*. The end *a* is suitably attached to the shaft. Near its middle parts the rod is doubly shouldered and surrounded by a cylindrical box or drum *cc*, which would be free to revolve around the rod but for a watch spring *rr*, one end of which is fastened to the rod *ab* and the other to the circumference of the drum *cc*. In this case the dial *dd* is attached to the front face of the drum, the index *nn* to the end *b* of the rod, and a scale *S* facilitates the reading as before. The outside of the box *cc* carries two vanes or propeller blades *pp* by which the rotation of the box is resisted. Suppose these removed or placed in the plane of rotation, no deviation would be indicated between the index and the dial however fast the system rotates. If however they are fixed in place (as in the figure), the angular deviation registered by the system of dial and index will in a general way be proportional to the square of the speed.

The instrument is capable of considerable adjustment so that it would appear to be adapted for measuring large ranges of speed. Thus one might alter the obliquity of the propeller blades, *pp*, relative to the plane of rotation, or by a suitable adjustment successively tighten or twist the watch spring *rr*. Consecutive notches would then correspond to given intervals of speed. The definite graduation would have to be made empirically, though it is seen that a subquadratic spiral is more

in keeping with the purposes of this apparatus than the simple spiral discussed above.

9. *Summary.*—For the measurement of activity by the above simple methods one would therefore couple the instrument's figures 5 and 6 in series to the same shaft and read both dials. It is conceivable however that the propeller blades *pp* of figure 6 may replace the friction pulley *p* of figure 5, particularly if provision is made for rotating the propeller in a liquid instead of in air. Suppose therefore that the dial and index of figure 6 has been standardized both with reference to the twist corresponding to one in degree of deflection and to the speed corresponding to the deflections. Then in an instrument of the type of figure 6, *a single reading would* at once *give the activity of the motor.* This is the final outcome of the method sketched in the above paragraphs.

Washington, D. C., May, 1894.

ART. II.—*On the occurrence of a large area of Nepheline Syenite in the Township of Dungannon, Ontario;* by FRANK D. ADAMS.

WHILE engaged during the past summer in making a geological reconnaissance of a portion of Eastern Ontario previous to a detailed mapping of the district for the Geological Survey of Canada, a large area of nepheline syenite was unexpectedly discovered.

The district in question lies between Lake Ontario and the Ottawa River, near the southern edge of the Archean protaxis, in the counties of Victoria, Peterborough and Hastings, in the province of Ontario, and comprises 3500 square miles, being sheet number 118 of the series of geological maps of Quebec and Ontario now in course of preparation by the Geological Survey of Canada. This tract of country which up to the present time has been, geologically speaking, a *terra incognita* was found to be occupied almost exclusively by rocks of the Laurentian system. The Grenville series with numerous heavy bands of crystalline limestone is extensively developed in the southern portion of the district, while to the north great tracts are underlain by what is believed to be the fundamental gneiss. In the extreme southeast corner of the district certain rocks occur which have been referred by Mr. Vennor to the Hastings Series.

The stratigraphical relations of these several series in this district have not as yet been determined, but will it is hoped, be worked out as the detailed mapping is proceeded with.*

* See "Preliminary Report on the Geology of a portion of Central Ontario." Ann. Rep. of the Geological Survey of Canada, 1891–92–93. Part J.

It is in the southeastern portion of this district in the townships of Dungannon and Faraday, in the county of Hastings that the nepheline syenite was discovered.

The mass is crossed by the well known Hastings Road, near the village of Bancroft, and is—roughly speaking — about eighty-five miles in a straight line northwest of Kingston, Ontario.

The area is a large one but its exact limits have not as yet been determined. It has however been traced in an easterly direction from a point in the township of Faraday, some distance west of Bancroft, to the York River on lots 12 and 13 or range XI of the township of Dungannon, a distance in a straight line of over seven miles. It also has a very considerable width.

As occurrences of nepheline syenite are rare, and this is the first one which has been found in the Laurentian system of Canada, and as, moreover, the rock presents a number of striking petrographical peculiarities, it has been thought that a preliminary notice of it at this time would be of interest.

Mode of occurrence and macroscopical character. — The mass occurs in the Laurentian and is flanked on the south, along a considerable part of its course by crystalline limestone. It is in many places intimately associated with a fine grained reddish biotite granite resembling aplite in appearance and which is apparently intrusive. The nepheline syenite is frequently massive in character, but usually possesses a somewhat streaked appearance, in places developing into a distinct foliation or gneissic structure, coinciding with that of the associated rocks. On the weathered surface little cavities are occasionally observed which are probably miarolitic druses. It is usually rather coarse grained, but in places becomes very coarse, as at the York River above mentioned, where nepheline individuals two and a half feet across were observed, with feldspar and mica crystals of corresponding size, while individuals one foot in diameter are numerous. On the weathered surface the nepheline and plagioclase which compose the great bulk of the rock can be readily distinguished, the former apparently dissolving away under the influence of the weather and presenting smoothly rounded surfaces of a gray color, like those so frequently seen in coarsely crystalline limestone. From these surfaces the plagioclase stands out in white chalk like grains or masses, while the other essential constituents of the rock are also readily recognized.

Microscopical character.—Under the microscope the essential constituents of the rock are seen to be nepheline and plagioclase, together with either a brown mica or a dark green hornblende. As accessory constituents, seldom absent and in

some cases present in large amount, are scapolite and calcite, and as less important and less abundant accessory constituents are garnet, zircon, sodalite, magnetite, pyrite and apatite. These latter, with the exception of garnet, always occur in very subordinate amount. Two or three other minerals occur in small amount in individual slides, or can be seen on the weathered surface of certain specimens, as these however could not be determined with certainty, without prolonged investigation their true nature is as yet doubtful.

The rock is usually very fresh and has a true hypidiomorphic granular structure. Evidences of pressure are in most cases entirely wanting. In a few slides however slight strain shadows and bending of twin lines are to be observed, and in one specimen distinct cataclastic structure was seen.

Nepheline.—This is by far the most abundant of all the constituents of the rock. It always forms the greater part of the rock and in many places, over considerable areas, the rock is composed of this mineral associated with a little mica or hornblende. The mineral is clear and colorless and is usually free from inclusions. It has a low double refraction and parallel extinction. On basal sections it is seen to be uniaxial and negative. It is easily etched by hydrochloric acid in the thin sections and can then be stained with fuchsine. In a few cases it was observed to be altered to muscovite. In hand specimens the mineral is seen to possess a luster which is vitreous rather than oily, so that it has been referred to as nepheline rather than as eleolite. An analysis of it is given by Dr. B. J. Harrington in the accompanying paper.

Plagioclase.—The rock contains no primary orthoclase, but feldspar though seldom very abundant is in most cases present, often in considerable amount. It is twinned polysynthetically, the bands being usually narrow and often indistinct. When cut at right angles to an optic axis it is seen to be biaxial. Its specific gravity, determined on two fragments taken from the very coarse grained variety of the rock at the York River, is 2·6207 and 2·625, while in a separation of the constituents of a specimen of the rock from lot 25 of range XIV of Dungannon, it was found to have a specific gravity of not over 2·623. The extinction on either side of the twinning line, measured on a cleavage fragment from the York River was $2\frac{1}{2}°$. These facts prove it to be an albite, with probably a very small percentage of lime.

Mica.—This constitutes the iron-magnesia constituent of the rock in three out of the five localities from which specimens were examined. In these cases it occurs alone, while in the other localities where hornblende is present the mica is absent. It is nearly black when seen in the hand specimens and in the

sections shows a very strong pleochroism, from pale yellow to a very deep brown. In basal sections it is seen to be distinctly biaxial but the axial angle is very small. It is usually quite subordinate in amount.

Hornblende.—Like the mica this constituent is usually present in comparatively small amount. It is always green in color and frequently presents more or less perfect crystalline outlines, with faces of the prism, clinopinacoid and domes. The prismatic cleavages at angles of about 124° are well seen. Two varieties have been observed. One of these from near the York River has a large axial angle and shows a pleochroism in tints varying from deep green to pale yellow, the absorption being $c > b > a$. Before the blow-pipe it fuses with intumescence to a black glass, giving at the same time a strong soda flame. This variety probably contains a considerable quantity of soda, but approaches common hornblende in composition. The second variety, which occurs in an exposure about two miles east of the village of Bancroft, has a much stronger pleochroism in tints varying from very deep bluish-green to a yellowish-green and has a small axial angle and a high extinction. Hornblende is not common in nepheline syenite and the only occurrence in which I have seen this particular variety is that which forms part of the Montreal mountain. Here what appears to be exactly the same hornblende occurs intergrown with augite. It has a very high specific gravity and is probably rich in soda and allied to arfvedsonite. A chemical examination of this hornblende will be made by Dr. Harrington.

Scapolite.—This mineral is present in about one-half of the slides and occurs in large clear colorless grains. It has the appearance of an original constituent. Basal sections present the usual double set of cleavages crossing at right angles while sections in the prismatic zone show a single set of cleavages with extinction parallel to them. In convergent light it is seen to be uniaxial and negative. The double refraction is much stronger than in the case of nepheline, the interference colors being tints of red, blue and yellow. The two minerals are therefore easily distinguished. As the occurrence of scapolite in such a rock is very unusual and in order to make sure that the mineral was not cancrinite, a thin section was treated with concentrated hydrochloric acid at first in the cold and subsequently with hot acid. The nepheline was strongly attacked and when the slide was subsequently treated with fuchsine became deeply colored. The scapolite however remained quite unaffected, even after the acid had been actually boiled upon the section. In another section also in which, under the action of the weather, the nepheline was quite de-

composed the scapolite was found to be still quite fresh. The uniaxial and negative character of the mineral together with the position of the cleavages, the strong double refraction, the parallel extinction and the deportment with acid, proves that the mineral is really scapolite.

Calcite.—The presence of this mineral in such a rock, as well as its mode of occurrence is very remarkable. The rock is quite fresh so that the calcite is not an ordinary decomposition product. Its mode of occurrence is that of an original constituent. It is found in well defined, more or less rounded, individuals, often of large size, occurring with, and often in, the other constituents of the rock. It has been observed completely enclosed by hornblende, nepheline, plagioclase, and garnet, the boundaries of the several minerals being quite sharp and the enclosing mineral being quite unaltered and normal in character. It shows the usual rhombohedral cleavages, is frequently twinned and sometimes has a fairly good crystalline form. It occurs in almost every slide, though usually in comparatively small amount. Individuals of considerable size are found in the very coarse grained variety of the rock at the York River. The origin of this calcite is a point which it is difficult to determine, although somewhat similar occurrences have been described in various other igneous rocks.* It cannot be a decomposition product in the ordinary sense of the term. Its mode of occurrence does not seem to indicate that it fills miarolitic cavities as Rosenbusch has supposed similar occurrences in certain granites to do. Had it been derived from the neighboring limestones some evidence of corrosion or alteration might be expected from the action of the very acid magma. Further study in the field may throw additional light on the question.

Garnet.—This is of a pale brownish or reddish-brown color and is always quite isotropic. It occasionally has a good crystalline form but usually occurs in more or less irregular shaped grains. It is present in most slides but seldom in large quantity.

Zircon.—Occurs in many slides and occasionally in the coarser variety of the rock in crystals of considerable size.

Sodalite.—At a number of places sodalite was observed in small grains or strings, scattered through the rock and it appears in one or two of the slides.

In certain parts of the area however it occurs in large masses.

* A. E. Törnebohm, "Om kalcithalt i graniter." Geol. Fören. i Stockholm Förh.. 1882, 140. G. W. Hawes, "Mineralogy and Lithology of New Hampshire," p. 207. See, also, F. D. Adams, "On some Granites from British Columbia and the adjacent parts of Alaska and the Yukon District." Canadian Record of Science, Sept., 1891.

Good specimens have been obtained from lot 29 of range XIII and elsewhere, but on lot 25 of range XIV of Dungannon it was found quite abundantly in what appeared to be veins and irregular shaped lumps. From some of these, masses of pure sodalite 10 by 10 by 4 inches in size were obtained, while considerably larger masses could probably be secured by blasting. It is probable that no other locality hitherto discovered in America affords such large masses of this mineral, with the possible exception of the nepheline syenite of the Ice River in British Columbia. The sodalite is bright blue in color and is often associated with strings of iron ore and traversed by little reticulating cracks filled with a reddish mineral which presents every appearance of a secondary origin and which Dr. Harrington finds to be orthoclase feldspar. It is believed that the sodalite may occur in sufficiently large masses to enable it to be profitably extracted and employed for ornamental purposes.

Summary.—The following points in connection with the composition of this nepheline syenite from Dungannon seem to be especially worthy of notice. Nepheline is always very abundant and in many large exposures the rock is an almost pure nepheline rock, consisting of nepheline with a little hornblende or mica. This variety of the rock is really an Ijolite* rather than a nepheline syenite. No orthoclase has been discovered in the rock, although twenty-five thin sections have been studied and some of them etched and stained. The constituents of two specimens were also separated out by means of Thoulet's solution. Its place is taken by an acid plagioclase, which in those cases where it has been examined has proved to be albite.

If the distinctive character of the variety of nepheline syenite named Litchfieldite by Bayley,† be the replacement of the orthoclase by albite, this rock is a more typical Litchfieldite than that from the original locality. The propriety of defining nepheline syenite as a rock composed essentially of nepheline and an alkali feldspar instead of one composed of nepheline and orthoclase is also rendered evident, as otherwise it would be necessary to classify this rock as a theralite from typical specimens of which it would differ greatly in composition. Like the Litchfield rock also this Dungannon rock contains neither augite nor sphene, but unlike it often holds scapolite and calcite.

Some years ago Prof. A. P. Coleman when investigating the petrographical character of the bowlders of the drift in the

* W. Ramsay and H. Berghell, "Das Gestein vom Iiwaara in Finnland." Geol. Fören. i Stockholm Förh., 1891, 304.

† W. S. Bayley, "Eleolite-Syenite of Litchfield, Maine, etc. Bull. of the Geol. Soc. of America, 1892, 231.

vicinity of Cobourg on the north shore of Lake Ontario, found among these bowlders a number composed of nepheline syenite. The rock composing these bowlders strongly resembles in many ways that described in the present paper. Orthoclase and microcline although present are exceeded in amount by the plagioclase. Eleolite or nepheline usually forms from one-quarter to one-half of the rock, while the rock is sometimes a nearly pure eleolite. "Biotite and hornblende much outweigh all the varieties of augite." Calcite grains were found in about one-third of the slides, sometimes "in the midst of the eleolite where their existence is hard to account for. What appears to be a scapolite occupies a similar position in four specimens" and a flesh red garnet also occurs in a few places.*

Cobourg lies a little to the west of south from the townships of Dungannon and Faraday, and it is highly probable, in view of the marked resemblances between these bowlders described by Prof. Coleman and the nepheline syenite occurring in these townships that the bowlders have been derived from this vicinity. The presence of orthoclase and microcline in many of the bowlders would indicate that all of them at least had not been derived from the actual area described in the present paper, but there is every reason to believe, from the reported occurrence of sodalite at other points in this district, that other areas of similar nepheline syenite exist here, and some of these have probably furnished the bowlders in question.

Petrographical Laboratory, McGill College, Montreal.

ART. III.—*On Nepheline, Sodalite and Orthoclase from the Nepheline Syenite of Dungannon, Hastings County, Ontario;* by B. J. HARRINGTON.

IN a recent report published by the Geological Survey of Canada and also in the preceding paper, Dr. F. D. Adams has called attention to a remarkable mass of nepheline syenite discovered by him in the township of Dungannon and Faraday, Ontario. The rock is in places exceedingly coarse in texture and individuals of nepheline, as much as two and a half feet in diameter have been observed. Dr. Adams has kindly placed a specimen of this nepheline in my hands for examination. It is from near the bank of the York River in Dungannon and has been found to have the following percentage composition:

* Trans. of the Royal Society of Canada, vol. viii, 1890.

Silica	43·51
Alumina	33·78
Ferric oxide	·15
Lime	·16
Magnesia	tr.
Potash	5·40
Soda	16·94
Loss on ignition	·40
	100·34

Hardness nearly 6. Specific gravity at 17° C. = 2·625 as determined with the bottle and 2·618 as determined by suspension with a hair. The specimen analyzed was white, subvitreous or slightly oily in luster, translucent, and sub-conchoidal to uneven in fracture. Before the blowpipe it fused quietly at about 3·5 to a colorless, slightly vesicular glass. It is described as nepheline rather than elæolite because of the luster being only slightly oily. The two names also seem unnecessary.

At a number of points in the region in question Dr. Adams found the mineral sodalite in the form of veins, streaks and irregular masses in the nepheline syenite. The masses were of various sizes, the largest observed being $10 \times 10 \times 4$ inches approximately. Specimens from lot 25 range XIV of Dungannon, which he has given me for analysis are weathered rusty superficially, but upon fresh fracture are of a fine smalt-blue color. They are traversed by a few little veins of a white and reddish mineral which proves to be orthoclase. The sodalite also contains scales of a dark brown to black mica. Some of the pieces were compact and microscopically showed no cleavage but one which was selected for examination showed distinct dodecahedral cleavage and vitreous luster. Its hardness was about 5·5 and its specific gravity at 16·5° C. was 2·295. On analysis the following results were obtained:

Silica	36·58
Alumina	31·05
Ferrous oxide	·20
Soda	24·81
Potash	·79
Chlorine	6·88
Sulphuric anhydride	·12
Water	·27
Insoluble	·80
	101·50
Deducting O = Cl	1·55
	99·95

The iron present was proved to be in the ferrous condition. On decomposing the mineral with nitric acid of 1·20 specific gravity, a residue was invariably left which did not consist of undecomposed sodalite. At first it was supposed to be silica which had separated from the sodalite, but on boiling with strong solution of sodium carbonate only a small proportion of it dissolved. This was included with the silica and the remainder, which contained a few minute grains of magnetite but which was not further investigated, was put down as "insoluble." What is given as water is the result of a direct determination, made by heating the powdered mineral in a combustion tube in a current of dry air and collecting the water in a chloride-of-calcium tube. A long piece of combustion tube was employed, so that if any sodium chloride were volatilized it would be condensed before reaching the chloride of calcium. The end of the combustion tube next to the latter was however found to be free from chlorides after the operation. Heated in a platinum crucible for half an hour at a low red heat, the mineral (after drying at 100° C.), lost 0·34 per cent of its weight. With increased temperature the mineral continued to loss weight slowly, and after heating to bright redness for about half an hour the total loss was 0·46 per cent. The sides and lid of the crucible were however coated with a film of sodium chloride. Heated in a closed tube the sodalite became perfectly white, while before the blowpipe it fused easily, with intumescence to a colorless glass.

As stated above the sodalite is in places traversed by little veins of a white and reddish mineral which proves upon analysis to be orthoclase. It is mostly dull but in places shows cleavage surfaces with a pearly luster. The reddish portions probably owe their color to the decomposition of iron pyrites, occasional grains of which still remain. The specific gravity at 18° C. was found to be 2·555 and analysis gave the following percentage composition:

Silica	63·00
Alumina	18·93
Ferric oxide	·59
Lime	·08
Magnesia	·09
Potash	12·08
Soda	3·67
Loss on ignition	1·00
	99·44

According to Dr. Adams the feldspar of the nepheline syenite in which the sodalite occurs is entirely plagioclase, and the occurrence of orthoclase as a secondary mineral in the sodalite is of special interest.

Chemical and Mineralogical Laboratory, McGill College, Montreal.

ART. IV.—*A new Design for large Spectroscope Slits;* by F. L. O. WADSWORTH. With Plate I.

OF the various forms of double motion spectroscope slits which have been designed, the two forms in most common use are the parallel ruler form, as fitted to most German instruments, and that form in which the jaws slide in guides and are moved simultaneously in opposite directions by a right and left hand screw. The first form is very convenient but requires very careful work in order to secure accurate results and is moreover apt to stick if the working parts are not kept clean. Moreover the jaws must be made somewhat longer than the available width of slit and the plate upon which they are mounted must be still larger to admit of room for mounting the levers, etc., etc., so that the whole arrangement becomes somewhat bulky in the case of a large slit. Another difficulty lies in determining the exact width of slit from the reading of the screw which is used to open it. The second form mentioned avoids all these difficulties except the last, but introduces others of a different character. As the screw is necessarily at one side of the jaw a twisting strain is thrown on the latter by the friction of the opposite guide tending to make the slit of unequal width at the two ends, and as the motion of the jaws is positive in both opening and closing there is danger of injuring the edges of the slit by screwing them too tightly together. For the same reason and also because there is no spring to take up the lost motion in the two screws, the zero point of the screw reading is uncertain and it is therefore difficult to determine the exact width of the slit from the reading of the screw. Prof. Langley had previously designed on this plan a very large slit with jaws 5^{cm} in length for his bolometric work in the infra red solar spectrum, in which the above difficulties were reduced to a minimum, by the accuracy and care with which the mechanical work was done, but which nevertheless showed after some usage a decided bluntness and want of parallelism of the edges.

As the size of the slit increases these difficulties of course grow more serious. When it became necessary therefore to provide a new and still larger slit having jaws with 10^{cm} clear opening, I proposed a new design which I had previously used with advantage in a double motion micrometer, in which the thrust of the screw on both jaws is central. As it appears to be new and as it possesses several advantages over either of the two forms previously noted a brief description of it may

be of interest. In fig. 1 is shown a rear view of the slit the back plate being removed to show the mechanism clearly. The two slit jaws slide between guides screwed to the front of the slit plate and each has a lug extending through this plate and projecting about 1^{cm} behind it. To the right hand jaw is screwed a ⅂ shaped bar d, the side arms of which pass around the ends of the slit and the center of which is opposite the lug on the left hand jaw. This lug is tapped to receive a screw on which are two threaded portions, one engaging with the thread in the lug and the other of just one-half the pitch of the first engaging in a nut h which is screwed to the slit plate. When therefore the screw is turned, say to the right, the jaws are separated by an amount equal to the motion of the point of the screw with reference to the threaded lug, say a distance x, while the whole jaw system is drawn to the right by the action of the fixed nut h a distance equal to $\frac{1}{2}x$ The center of the slit therefore remains fixed, the jaws opening out from it. A spring bearing against the lug on the left hand jaw provides for the return motion and takes up all back lash in the screw. The graduated head gives by its motion over the graduated drum the whole number of turns and fractions of a turn enabling the width of slit to be determined at a glance. It will be noted further that the accuracy of separation depends only on the accuracy of the screw which works in the slit lug, the screw at h serving only to keep the jaws centered. As the motion is positive in one direction only (on opening), as in the case of a single motion slit, there is no danger of injuring the edges of the slit by turning the screw too far.

Further and perhaps most important of all in a slit of this size, the thrust of the screw on both jaws is central and there is consequently no tendency to twist the jaws in their guides. The new slit has been constructed by Grunow, who has as usual admirably executed the work. A front view of the new slit is given in fig. 2 and to show its compactness and also its great size as compared with the usual spectroscope slits, two of these each having a clear opening of 2^{cm} and representing the two types already described are shown at its side.

Astro-Physical Laboratory, Smithsonian Institution,
Washington, D. C., March, 1894.

FIG. 2.

FIG. 1.

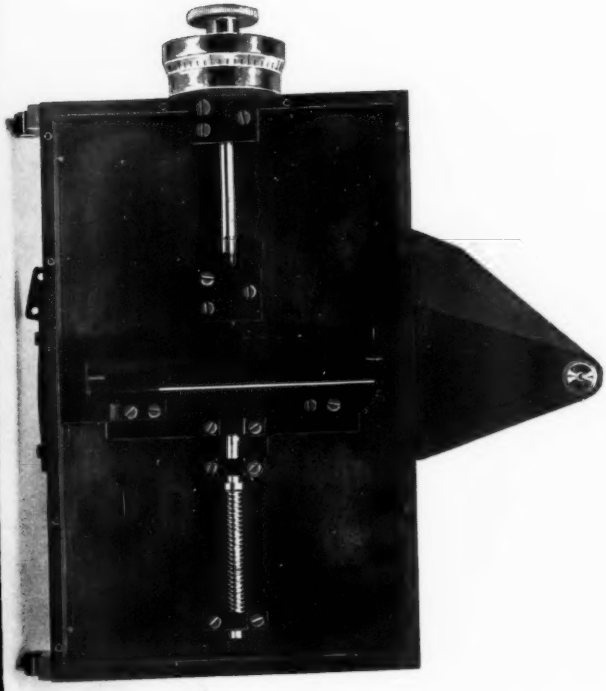


FIG. 1.

ART. V.—*Tertiary Changes in the Drainage of Southwestern Virginia;** by MARIUS R. CAMPBELL.

IT has been recognized for a long time that isostatic movements have been active in the Appalachian region throughout post-Paleozoic time. Their exact character has never been worked out, nor has their influence on the physiography and drainage of the region been fully appreciated. Certain phenomena have, by a few workers, been attributed to movements of this kind but in such cases they have been referred to broad epeirogenic rather than local orogenic movements. The writer is fully convinced that the local movements have been more important in shaping both the physiography and the drainage of the region than the broader and more general movements and offers the following observations concerning a reversal of drainage, in support of the statement.

Along the northwestern border of the Appalachian valley, from Cumberland gap northeast, there is a great synclinal trough of Coal Measures, bounded on the northwest by Pine mountain and on the southeast by Stone mountain or the Cumberland escarpment. The edges of the trough are formed by the Carboniferous conglomerate, a hard and resisting stratum which has been chiefly instrumental in turning the streams to subsequent courses. The change in drainage, here described, occurred within this syncline, about 70 miles northeast of Cumberland gap.

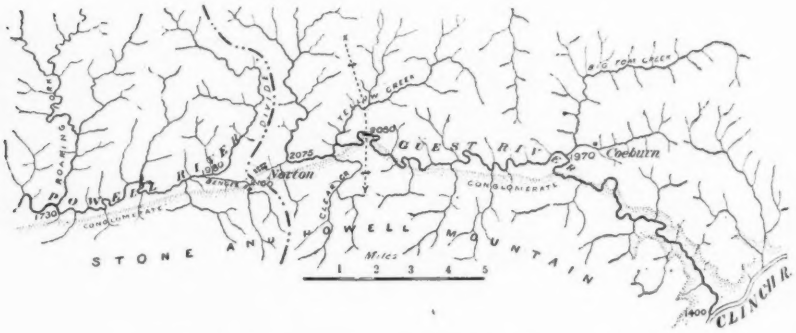
The region in question is drained by Guest and Powell rivers which rise in the Black mountains and flow south in parallel courses to Norton, where they encounter the conglomerate rising on the southern rim of the syncline. To avoid this, Powell river turns west, whereas Guest river turns east. They are but a mile apart at these bends and separated by a very low divide. Powell river flows westward within the synclinal rim to Big Stone gap which it has carved through the conglomerate barrier; through this gateway it enters the head of a broad, open valley eroded in the great Silurian limestones which it follows until it joins the Clinch river 15 miles north of Clinton, Tenn. Guest river turns eastward and flows around the end of Powell mountain, joining the Clinch river a few miles below St. Paul, Va.

In the basin of Powell River (fig. 1) the drainage appears normal, showing that mature adjustment to structural features which is found only in systems of great antiquity. The changes occurring in the past have been so remote that all traces are obliterated, both in the physiography and in the

* Published by permission of the Director of the U. S. Geological Survey.

arrangement of the drainage lines. Guest river, from the Norton divide to Coeburn, exhibits unmistakable evidence of a reversal of its course. All the tributaries, in this interval, turn westward to join the river which flows due east. They thus form a very acute angle where they unite. The present position of these tributaries is found to bear no particular relation to the geologic structure, but to be due to some condition affecting the stream alone.

1.



The tributaries which enter the river above the mouth of Tom creek from the south flow, throughout their upper courses, in gorges cut in the heavy conglomerate of Powell mountain and much of their irregularity is due to the way in which they cross its various hard beds. Before reaching the river they emerge from the mountain and flow, for perhaps a quarter of a mile, across the level surface of a shale valley. Their normal course in this plain would be northeast, but in every case they turn northwest. Below Coeburn there are several small branches which in general appear to follow the same law, but their courses were determined by the geologic structure and hence cannot be used as evidence of reversal.

On the north side of the river there are three main branches which show this westward deflection even more strikingly than the southern tributaries. Big Tom creek, joining the river near Coeburn, has a decidedly westward course not in harmony with the present conditions. Geologic structure did not determine this bend in the creek, since the rocks are approximately horizontal except in the immediate vicinity of the mountain where there is a gentle northerly dip away from the anticlinal axis. Yellow creek also affords a good example of this westward deflection, for in persevering in its course the stream has been obliged to cut diagonally across a small anticline (*x y*,

fig. 1) although the easier course would have been to join the river east of this fold. This cross anticline, pitching rapidly northward, has arched the strata in such a manner that the conglomerate, at this point, extends much beyond its general line of outcrop. Guest river originally flowed across this projecting point without coming in contact with the hard stratum, but in later ages it has removed the softer rocks and reached the main conglomerate. The stream has slowly migrated down the slope of the hard bed, forming a great northerly bend at the point where the axis crosses the river. No such formidable barrier intersects the course of Yellow creek, but in the measures above the conglomerate there are many hard sandstones which would doubtless have a tendency to shift the course of the stream.

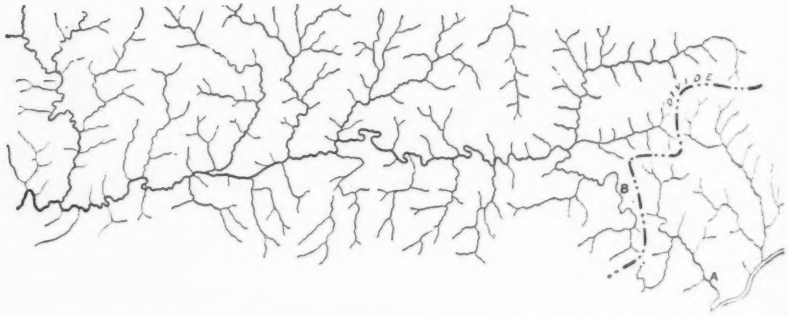
The acute angle made by Guest river itself at Norton is equally remarkable and cannot be explained by the present course of the river, since there is nothing to prevent this stream from avoiding Norton altogether and joining the river near the mouth of Yellow creek. If Guest river were a mature stream this would certainly have been accomplished and Yellow creek also would have been shifted to the eastward in accordance with the present conditions. But the system is not adjusted to the surrounding conditions; it has the marks of immaturity, of adjustment to conditions which no longer exist and which were radically different from the present.

The divide between Powell and Guest rivers is no more conspicuous than that between any two tributaries of the same stream; but being quite narrow it has the appearance of exceeding them in altitude. The country is essentially a deeply dissected plateau with the water partings standing at or near the original surface. Along the northern side of Stone and Powell mountains there is a valley due to the combined effect of a line of outcrop of soft shale and great disturbance of the strata in the uprising of the Powell Valley anticline. This valley has been accentuated by the work of the rivers under consideration, for they have naturally availed themselves of the most favorable location and have carved deep channels throughout most of its extent. In view of these structural facts, we might expect to find a low gap in the divide between the two drainage basins, but it is even lower than would be expected. Furthermore a distinct channel across it is still visible and a deposit of white sand and clay rests upon its highest point at Norton.

Thus it seems certain that at no very remote time, geologically speaking, there was a large stream flowing across this divide; it seems equally certain that the direction in which it

flowed was west; and that its drainage basin included the present basin of Guest river as far east as Coeburn. Figure 2 shows the ancient drainage reconstructed in accordance with the above facts. Powell river then had its source on the plateau east of Coeburn; it flowed along the present valley of Tom creek to Coeburn where it turned due west, receiving

2.



the various tributaries as they flow to-day and joined the present Powell river a mile west of Norton. Before the change occurred, Clinch and Powell rivers were flowing at about the same elevation, but this was probably very much nearer sea level than the streams flow at present. In the contest between their headwaters, the Clinch was retarded by the upturned edge of the Carboniferous conglomerate against which the main stream and its tributaries could make but little headway, while Powell river was not hindered by any obstruction. Under these conditions the divide between them had migrated back quite close to Clinch river as shown in fig. 2. Being thus adjusted to the surrounding conditions, the two rivers would have remained in equilibrium unless their balance was disturbed by an external cause. This cause must have been isostatic movement since no other kind of movement is known to have occurred in late geologic time. But was it an epeirogenic or orogenic movement that caused the change? A broad uplifting of the district could not have produced this effect for the relative position of the two streams would have remained unchanged, therefore it must have been caused by a local or orogenic uplift. Our conclusion however need not be based upon this negative evidence for the region abounds with positive proof of the warping of the earth's crust.

The upper portion of the Clinch valley presents the youthful features of a recently revived stream. Its character was first recognized by Willis in 1885 and later studied in detail by the writer. The river flows in a narrow channel 300 to 700

feet deep which it has carved in the calcareous strata of the Cambrian and Lower Silurian. Its larger tributaries have nearly kept pace with the river in the corrasion of their channels, but the smaller ones have only succeeded in cutting narrow V-shaped gorges through which they discharge their waters into the main stream. The Holston, a larger stream, flowing parallel to the Clinch and 20 miles southeast of it, has only cut from 50 to 100 feet below its ancient valley.

This shows greater elevation of the Clinch drainage basin or a differential uplift with its maximum development in the region northwest of Clinch river, sloping gradually southeast to a minimum in the valley of the Holston. While this uplift was purely orogenic in character, it must not be supposed that it formed steep slopes in both directions away from the axis of the fold, but rather that it raised the surface in a low broad ridge along a certain axial line which can be located only in the most general way. Judging from evidence obtained in a more extensive study of the field, this axis passes north of Norton but at what distance it is difficult to determine. Along the crest of the fold there was probably a broad belt where but little tilting occurred which accounts for the unaffected condition of the northern tributaries of Powell and Guest rivers.* The surface southeast of this axial line being thus tilted, those branches flowing southeast to the Clinch river would be accelerated, while the headwaters of Powell river would be retarded since they flow toward the axis of uplift. Clinch river having a greater volume of water than Powell river would more rapidly deepen its channel even though it had to contend against the upturned conglomerate. The branch A, fig. 2, flowing on the soft shales above the conglomerate, easily cut back along the strike and diverted the head branches of Powell river; first the small one B from the southeast was conquered which pushed the divide to Coeburn; Tom creek was captured at this point and the process of robbing was greatly accelerated by the increased volume of water derived from that stream; as time progressed, the conquest extended westward until at last it reversed the entire drainage east of Norton. This robbing could be easily extended so as to include Benges branch which comes out of the mountain upon almost the summit of the divide and flows west to Powell river. Should Guest river lower the divide but 20 feet this branch would flow to the eastward, but this change is not likely to occur since Powell river is much more actively at work on this divide than Guest

* A fuller discussion of this evidence is given in the Geomorphology of the Southern Appalachians by C. Willard Hayes and Marius R. Campbell. Nat. Geog. Mag., vol. vi.

river. The chances are in favor of the former stream recapturing some of its lost territory.

This career of conquest so well begun by Guest river was stopped short by an obstruction in its pathway. The river soon removed the soft shales upon which it was originally located and encountered the massive, horizontal conglomerate which soon absorbed all of its energies. This work has greatly retarded the development of its upper course which has remained almost stationary and has retained all of its inherited characteristics. In the great bend below Yellow creek, this massive conglomerate has again obstructed the course of the stream and still more retarded the development of its head branches.

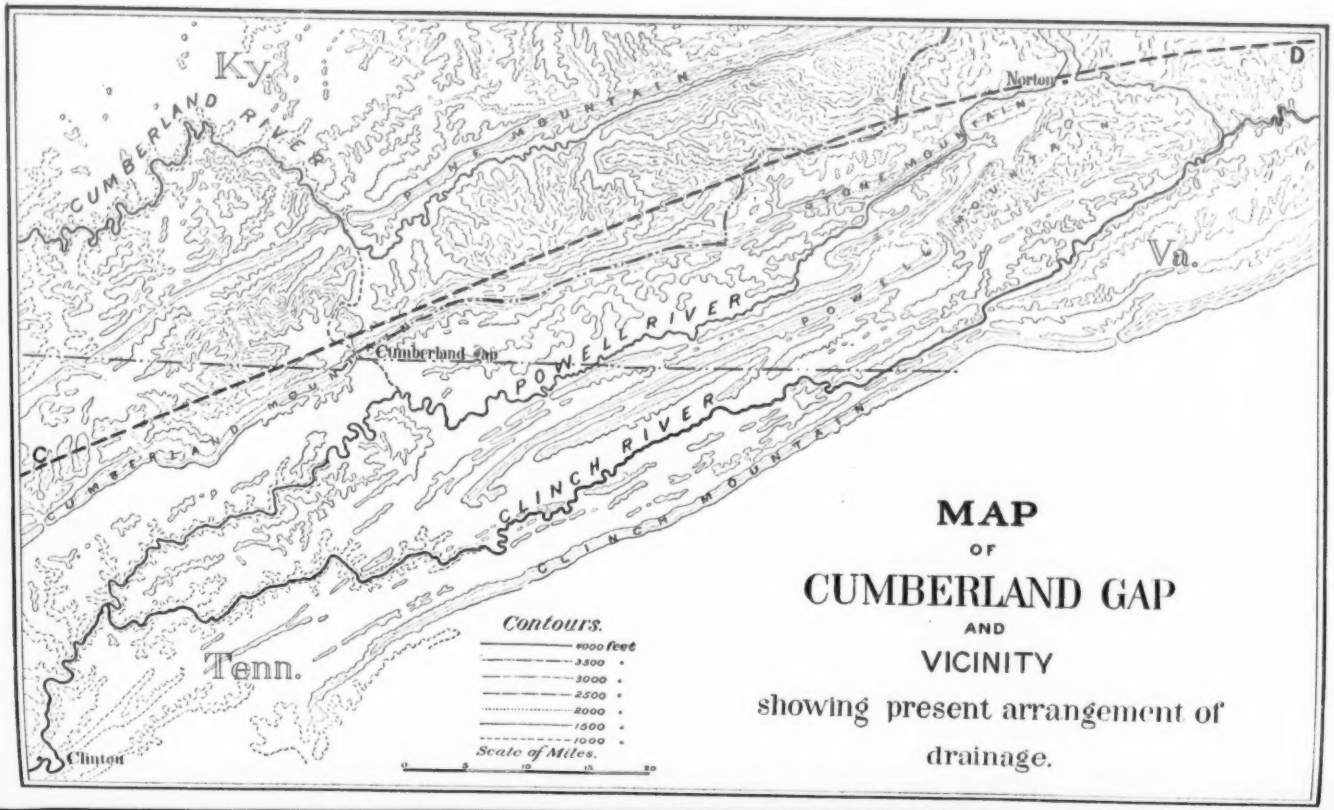
The reversal was accomplished after the Tertiary period of base leveling, for the uplift along the axis C D warped the Tertiary peneplain as described above and hence must have occurred after the completion of that topographic feature. The amount of corrasion accomplished by Guest river since the change, requires a large allowance of time; therefore it seems probable that the change occurred soon after the completion of the base-leveling period or in late Tertiary time.

Altogether the evidence seems quite conclusive (1) that such a change occurred; (2) that it was accomplished soon after the completion of the Tertiary peneplain; and (3) that its cause was the orogenic uplift along the axis C D.

In connection with the case above described, the writer wishes to call attention to another probable adjustment of drainage due to the same orogenic uplift; a change which accounts for some peculiar topographic features now apparently anomalous.

Cumberland gap, that historic gateway between the east and the west, is but a wind-gap in the Cumberland escarpment and is remarkable chiefly on account of the depth to which it is cut. That its history is different from the history of the ordinary wind-gaps in the ridge is apparent, but the only explanation yet offered regarding its origin is that by Shaler who attributes it to retrogressive erosion along a local cross-fault.* That a fault of this character determined the location of the gap seems quite probable but it is not so clear that sub-aerial erosion could reduce it to its present condition. The writer is familiar with several such cross-faults, but knows of no case in which a remarkably low gap has been produced by them unless corraded by a stream of water. If we assume for the present that Cumberland gap is due to stream corrasion, then there are three questions which must be answered. (1) What stream

* Kentucky Geological Survey, vol. iii, New Series, pp. 98–99.


Ky.
CUMBERLAND RIVER
PINE MOUNTAIN
Norton
D
Va.
POWELL MOUNTAIN
POWELL RIVER
Cumberland Gap
CUMBERLAND MOUNTAIN
CLINCH RIVER
CLINCH MOUNTAIN
Tenn.
Clinton
Contours.
1000 feet
2000 "
2500 "
3000 "
3500 "
4000 "
Scale of Miles.
0 5 10 15 20
MAP
OF
CUMBERLAND GAP
AND
VICINITY
showing present arrangement of
drainage.

could have occupied the gap; (2) what conditions changed its course; and (3) when did this change occur?

The accompanying map shows in a general way, by means of 500 foot contours the configuration of the country. The great valley bordering the Cumberland escarpment on the southeast is called Powell valley and in this during the Tertiary period the limestones were reduced almost to baselevel. Since then the plain has been tilted so that at the northeastern corner of the area, covered by the map, its present elevation is about 2,000 feet, sloping gradually to about 1,500 feet at Cumberland gap and 1,200 feet in the extreme southwestern corner of the sheet at Clinton, Tenn. The Cumberland river valley was partially baseleveled at about this same elevation, but the rocks are harder and the reduction was not so complete. A very significant fact about Cumberland gap is that its elevation (1,383 feet)* is less than the Tertiary baselevel peneplain on either side. This shows that, after the completion of the peneplain, the stream occupied the gap long enough to reduce it at least 100 feet below the former baselevel. An uplift following a period of base-leveling would stimulate erosion very much and the streams would rapidly deepen their channels, but on the other hand the lower courses of a stream must be cut before it can deepen its channel near headwaters, so it is probable that considerable time elapsed between the completion of the peneplain and the diversion of the stream that carved the gap. This agrees with the probable date of change in Guest river and indicates that the same uplift is responsible for both.

Thus we can with considerable confidence establish the date at which this change occurred. Now it remains to be seen whether we can locate the stream that was then diverted from the gap. Did Powell river then turn north and join Cumberland river or did the Cumberland flow south and join Powell river? The headwaters of the Cumberland probably did not flow south, for the gorge through Pine mountain must have been occupied since Cretaceous time; therefore no change could have been made in that stream as late as the Neocene. In regard to Powell river there are some facts that support the idea of a northward flow. This stream as already described follows the Powell valley throughout most of its course. From Jonesville, Va., to a point opposite Cumberland gap, the river flows closely along the southeastern side of the valley in a normal course, but at the latter point it turns abruptly and flows toward the gap for a distance of five miles. In thus

* Elevation given by the profile of the Cumberland gap extension of the Louisville and Nashville Railroad.

deviating from its course, it leaves the soft Chickamauga (Trenton) limestone and cuts across the siliceous Knox dolomite to a point about four miles from the gap and on the axis of the anticline; here it makes another sudden change and follows the axis to the southwest. This peculiar bend in the river cannot be explained by existing conditions; it appears to be an inherited course from an older river which turned at this point and flowed northwestward through Cumberland gap.

The Cumberland river was probably one of the principal streams draining the Appalachian highlands before the close of the Paleozoic era and it held its antecedent course long after the Cumberland plateau was elevated above sea-level. The great river flowing southwest in the Appalachian valley encroached upon the headwaters of the Cumberland and gradually diverted its upper tributaries. In Cretaceous time Powell river was the sole surviving member of the Cumberland river system within the Appalachian valley. It held its antecedent course to the westward during the elevation which followed the Cretaceous period of baseleveling and carved deep gorges in Pine and Cumberland mountains. It maintained this course while the surface was again reduced to a peneplain, but in the succeeding uplift, it was diverted. Thus Cumberland river lost its last hold on the Appalachian valley.

The axis of orogenic uplift which affected the headwaters of Powell river so disastrously passes just west of Cumberland gap. Previous to the uplift, Cumberland river was barely holding its own against the encroaching Appalachian river; when the uplift occurred athwart its course it was forced to yield its last tributary to its more favorably located rival, Clinch river. A small branch working back along the axis of the Powell Valley anticline tapped Powell river above the rising fold and turned its waters into the Tennessee system.

Thus in all probability a slight orogenic uplift was the direct cause of a complete change in the drainage of this region,—a change radical in its effect but now indicated alone by the deserted gorge of Cumberland gap.

ART. VI. — *On some Methods for the Determination of Water;* by S. L. PENFIELD.

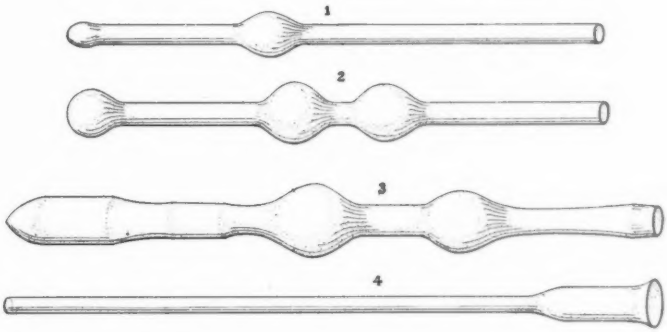
THE accurate determination of water is sometimes one of the difficult operations of analytical chemistry. This is especially the case when water is not completely expelled from a mineral at a temperature which can be obtained in a hard glass tube with an ordinary gas combustion furnace, and especially when either the loss of some volatile constituent or an increase in weight by oxidation renders it impossible to make the determination by loss on ignition. The tubulated platinum crucible described by Gooch* furnished a solution of the problem, but the apparatus is expensive, and the author has found it necessary to surround the crucible in which the fusion is made with an outer one containing some fusible salt like sodium carbonate, in order to prevent the passage of gases through the red hot platinum, which would render the results of the determination too high. This makes the apparatus more complicated, and the expansion and contraction of the fused salt between the crucibles strains the apparatus to such an extent that repairs are frequently necessary. The use of a platinum tube, wrapped with repeated layers of asbestus paper soaked in borax to prevent the passage of gases, has been suggested by Chatard,† but the apparatus is both expensive and complicated.

The author's experience in testing minerals for water has suggested the possibility of making an accurate determination by heating a weighed quantity of mineral in a closed glass tube, weighing the tube plus the water, then drying and weighing again. It has been found, as will be shown in the course of this article, that the method is very accurate and makes it possible to obtain direct water determinations without the use of absorption tubes, or any system of drying apparatus. The method is not altogether new, as it has been used by Prof. G. J. Brush‡ in the analysis of Sussexite, $H(MnMg)BO_3$. In this case after the water had been expelled and the tube weighed, the water was dried out in a vacuum over chloride of calcium, when the tube was again weighed and the percentage calculated from the loss.

From the author's experiments the following conditions may be recommended as favorable. The shape of the closed tubes depends upon the quantity of mineral that is to be experi-

* Am. Chem. Jour., ii, p. 247, 1880.
† Amer. Chem. Jour., xiii, p. 110, 1891.
‡ This Journal, II, xlvi, p. 240, 1868.

mented upon, the ease with which the water is given off and the necessity of adding some substance in order to retain a volatile constituent. A simple hard glass tube closed at one end, of about 6^{mm} internal diameter and 20–25^{cm} long can often



be used, while some of the forms that have been found more convenient are represented in figures 1 to 3.* Number 3 may be drawn out from ordinary combustion tubing. These tubes must be thoroughly dried inside, which is best accomplished by heating and aspirating a current of air through them by means of a glass tube reaching to the bottom. This is a necessary precaution and should always be taken even if the tubes are apparently dry. In order to bring a weighed quantity of the substance into the lower end of a tube without depositing any of the material on the sides, a thistle tube, fig. 4, is employed. This is conveniently cleaned by drawing through it a bit of dry cotton attached to a fine wire.

For heating, a Bunsen burner or blast lamp flame may be used, according to the temperature required. The water that is expelled condenses in the cold part of the tube, but cannot escape as there is no outward current to carry it along, except a very slight one caused by the expansion of the air when the tube is first heated. To guard against any possible circulation of currents of air however, which might carry off traces of water, a short piece of glass tube drawn out to a capillary, fig. 5, is joined on by a rubber and is removed before weighing. While being heated, the tube may be held by a clamp or in the hand, and if the quantity of water is considerable it should be expelled slowly and driven up into the first bulb, figs. 2 and 3, to prevent its flowing back upon the hot glass. To prevent

5.

* In making the ignition tubes considerable time may be saved by fusing new bottoms on to those that have previously been used.

the upper part of the tube from becoming heated by radiation from the flame, a screen of asbestus board can be used, or still better a strip of wet cloth may be wrapped about the bulbs and upper part of the tube, and this may be further cooled if necessary by applying water from a wash bottle. After the water has been expelled, the glass is fused down upon the substance, so as to make its volume as small as possible, and the end containing the substance pulled off. It is not always necessary to do this, but it usually is best. The tube containing the water is wiped clean, cooled and weighed. The water can be quickly removed by heating and aspirating out the steam and moist air, when the tube after cooling is again weighed. To test the accuracy of the method experiments were made with transparent, colorless gypsum from Sicily. The mineral, which is assumed to be pure and to contain 20·93 per cent of water, was ground and weighed out air dry from a weighing tube. The results are as follows:

	Gypsum taken.	Water calculated.	Water found.	Error.
1.	·20985	·0439	·0442	·0003 +
2.	·2417	·0506	·0505	·0001 —
3.	·2642	·0553	·0553	·0000
4.	·3505	·0734	·0731	·0003 —
5.	.4913	·1028	·1028	·0000
6.	·6457	·1351	·1352	·0001 +
7.	2·0000	·4186	·4195	·0009 +
8.	5·0643	1·0600	1·0623	·0023 +

To these may be added some determinations made on calamine and natrolite, which by direct ignition in a crucible lost 7·76 and 9·80 per cent of water respectively.

	Calamine taken.	Water calculated.	Water found.	Error.
9.	·5301	·0411	·0406	·0005 —
	Natrolite taken.			
10.	·1838	·0180	·0176	·0004 —
11.	·2553	·0250	·0247	·0003 —
12.	1·0000	·0980	·0980	·0000

These results indicate that the method is very accurate for the determination of both large and small quantities of water and experiments 7 and 8, which show the greatest apparent variation, are within ·045 and ·04 per cent of the theory respectively.

To test the method where substances have to be added to retain volatile products, experiments were made with pure recrystallized cupric and ferrous sulphates, containing 28·87 and 45·32 per cent of water respectively. To prevent the escape of SO_3 some strongly ignited lime was mixed with the powdered salts before heating. The mixing can best be done

in the tube by means of a fine wire, bent into a corkscrew coil at the end. The results are satisfactory and are as follows:

	$CuSo_4 . 5H_2O$ taken.	H_2O calculated.	H_2O found.	Error.
1.	·2458	·0887	·0885	·0002 −
2.	·3532	·1274	·1270	·0004 −
3.	·3613	·1304	·1296	·0008 −
4.	·3779	·1363	·1359	·0004 −
5.	1·7587	·6347	·6343	·0004 −
	$FeSO_4 . 7H_2O$ taken.			
6.	·1138	·0516	·0516	·0000
7.	·2150	·0975	·0978	·0003 +

It frequently happens that water is to be determined in compounds which give off carbon-dioxide on ignition, as for example in rock analysis where calcite is present, and to test the application of the method in such cases experiments have been made with pure, recrystallized bicarbonate of potash, which yields 8·99 per cent of H_2O and 22 per cent of CO_2 on ignition, and also with gypsum mixed with calcite. It is evident that carbon-dioxide will displace the air in the tube and must be removed before weighing. This may conveniently be accomplished by holding the tube at an inclination of about 40°, with the cap removed and open end down, so that the heavier carbon-dioxide can flow out. At first the tube diminishes rapidly in weight, but after three hours the loss becomes almost constant and amounts to very nearly 0·0003 grams for every hour that the tube is left open. A correction therefore of that amount must be made. Moreover, the carbon-dioxide which passes out of the tube will carry water vapor with it, but if the amount of the gas that is liberated is known a correction may be made. Assuming that the gas is saturated with water vapor, and passes out of the tube at a mean barometric pressure of 760^{mm} and a temperature of 20° C., 1 gram of it would carry off ·0096 grams of water. In the following series of experiments the tubes were left open in an inclined position for three or more hours, and in addition to the time correction, one was made for the water carried off by the escaping CO_2, which amounts to ·0021 gr. for every gram of $HKCO_3$ taken.

	$HKCO_3$ taken.	H_2O calculated.	H_2O weighed.	Corrected weight.	Error.
1.	·2694	·0242	·0225	·0242	·0000
2.	·4641	·0417	·0395	·0418	·0001 +
3.	·5064	·0455	·0438	·0458	·0003 +
4.	1·0055	·0904	·0869	·0902	·0002 −
5.	1·0089	·0907	·0881	·0912	·0005 +
6.	1·5109	·1357	·1312	·1357	·0000
7.	2·0000	·1798	·1747	·1796	·0002 −
8.	2·7690	·2489	·2393	·2463	·0026 −

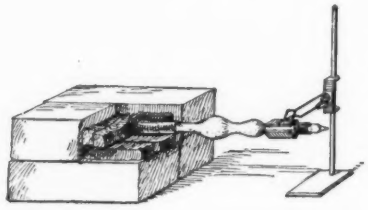
The greatest deviation from the theory in this series is in No. 8 which shows a loss of 0·10 per cent.

In the experiments with gypsum mixed with calcite it cannot readily be told how much CO_2 is expelled, since it is not known to what extent the calcite is decomposed. The only correction that has been made therefore is for the time that the tubes were left open.

	Gypsum taken.	Calcite taken.	H_2O calculated.	H_2O weighed.	Weight corrected.	Error.
1.	·2668	·1000	·0558	·0549	·0558	·0000
2.	·3503	·2000	·0733	·0712	·0721	·0012 –
3.	1·0000	1·0000	·2093	·2084	·2093	·0000

The results thus far given are very satisfactory, and they represent all the determinations made after the method was perfected. In the case of minerals, however, which give off water only on intense ignition, it was found that the tubes could not be heated sufficiently over the blast lamp. A long series of experiments was made with talc, chondrodite and staurolite, using lead oxide, bismuth oxide and a mixture of lead oxide and sodium carbonate in the tubes as fluxes, but the results were not satisfactory. It was evident that a more intense heat must be obtained, and accordingly the following method of heating was devised. A sort of oven was constructed of fire brick lined with pieces of charcoal,* fig. 6. The best tube to use with this furnace is one like fig. 3, made from combustion tubing. To protect the glass the lower end is surrounded by a cylinder of platinum foil. This is applied by first bending the metal about a tube considerably smaller than the one to be used, and then springing it over the end of the ignition tube. If properly adjusted the spring of the platinum will hold it securely in place. The tube is held in the furnace as shown in the figure. An additional piece of charcoal is placed on top of the tube and the blast lamp is turned to a horizontal position so that the flame plays upon the side of the apparatus. The temperature that can be obtained by this method of heating is very intense, bringing the apparatus

6.



* Where fire brick are not at hand ordinary brick will answer, but they soon crack with the intense heat. The charcoal that is most convenient to use is that which comes prepared for blowpipe purposes.

to a full white heat. The flame glances off from the charcoal and it is necessary to have the tube carefully screened by asbestus board, in addition to having a wet cloth around the bulbs. After the ignition is finished a glass tube is fused to the platinum to hold it, and the end of the tube is pulled off. The platinum foil can be separated from the glass by plunging it while hot into cold water, when the glass readily cracks away. For testing the efficiency of this method of heating, experiments were made with talc from Fowler, N. Y. The material was not absolutely pure and, therefore, the degree of accuracy must be determined by the agreement of a series of determinations.

	Talc taken.		Water weighed.	Per cent.
1.	·5000	Heated alone	·0232	4·64
2.	·5000	Mixed with 0·50 gr. CaO	·0224	4·48
3.	·5000	" " 0·75 " PbO	·0230	4·60
4.	1·0100	" " 1·50 " "	·0451	4·47
5.	·9637	" " 2·00 " "	·0426	4·42

The talc contained some fluorine, since when heated alone the tube was slightly etched and the water distinctly acid, the percentage in No. 1 is certainly, therefore, somewhat high. A mean of Nos. 2, 4 and 5, 4·46 per cent is probably very nearly correct. The amount of lead oxide to be taken as a flux depends upon the fusibility of the mineral. With an infusible compound like talc, an amount equal to twice the weight of the mineral would be near the limit, while with a more fusible one very much less should be used. All that is necessary is to have the contents of the tube fuse so as to insure a complete decomposition, and if the mixture is too fusible it may eat its way through the glass, not only spoiling the experiment but probably injuring the platinum. Lead oxide, taken in small quantities, cannot always be relied upon to hold fluorine. Thus in trying to determine water in topaz, 1 gram of the mineral was fused with twice its weight of the oxide but the water that came off was very strongly acid. The lead oxide used in these experiments was a good quality of litharge, heated to near its fusing point to drive off water or any volatile matter. The material is not hygroscopic, and can be kept for a considerable time exposed to the air without suffering any appreciable increase in weight.

The intense heat which can be obtained with the charcoal furnace already described makes it possible to decompose a mineral completely by fusion with sodium carbonate in a combustion tube, and to collect the water in a weighed sulphuric acid or chloride of calcium absorption apparatus. For this purpose a piece of combustion tubing of 15^{mm} internal diam-

eter is drawn out like fig. 7. The end is rounded and flared out a little. Two clylinders of platinum are next adjusted, one on the inside the other on the outside. These are made from pieces of platinum foil, about ·07^{mm} in thickness and

7.

8×11^{cm} in diameter, which have previously been bent around glass tubes of such a size that when applied to the combustion tubing the spring of the metal will hold them in place. A large platinum boat, 7 to 8^{cm} long and 11 to 12^{mm} in diameter with a cross section like fig. 8, should be used, since this will readily hold a gram of mineral mixed with 5 grams of sodium carbonate. Sodium carbonate dried at near its fusing point is not very hygroscopic. Thus 2·5 grams of it, spread out on a watch glass gained only ·0002 grams in 15 minutes. After the boat containing the mixture has been shoved within the platinum casing, the tube is connected with a suitable drying and absorption apparatus and heated in the furnace which is constructed like fig. 6 except that only three bricks are used. The tube is placed in the angle formed by the charcoal lining, some pieces of charcoal are placed at the sides in front, leaving an opening through which the flame may be directed, and an additional piece is laid on top. The tube can readily be brought to a full white heat, and by *forcing* a slow current of dry air through the apparatus the carbon-dioxide resulting from the decomposition can be removed, and the water carried over into the weighed absorption tube. The glass fuses between the platinum casings, and in a number of experiments that have been tried there has not been a single instance where the glass tube has broken or shown any indication of leaking. After heating, the tube will not crack if it is left to cool slowly on the charcoal, but it cannot be used a second time as it will be very apt to break where the platinum is fused on to the glass. At the high temperature to which the glass is subjected, it of course becomes very soft and the ends must be properly supported, also the rubber connections and absorption apparatus must be carefully screened by asbestus board. By constructing a cover for the boat no material need be lost by spattering, and after making the water determination the contents may be used for the remainder of the analysis. With some samples of topaz that were experimented upon, the escaping carbon-dioxide carried off traces of the mineral and sodium

8.

carbonate in the form of fine dust, but its passage into the weighed absorption apparatus was prevented by a loose plug of fine asbestus, slipped into the tube after the boat was in place.

Three determinations of water, made on the same sample of talc that was used for testing the previous method, gave 4·46, 4·37 and 4·44 per cent, a mean of 4·42. At the conclusion of an experiment the platinum foil can readily be removed from the glass by heating and plunging into cold water, and may be flattened by rolling with a glass tube. This method is one that is applicable for the determination of water in all cases of mineral analysis, and if carefully executed the results are very accurate. In its essential details, decomposition by fusing with an alkali carbonate and collecting the water in a weighed absorption apparatus, it is similar to the methods of Ludwig* and Sipöcz.† The former suggested the use of a specially constructed platinum tube in which the mineral was fused with a mixture of dry sodium and potassium carbonates, the latter made use of a porcelain tube and the fusion was made with the mixed carbonates in a platinum boat. The use of a glass tube has a decided advantage over platinum and porcelain, since the operation may be watched and the intense heat that can be obtained with the charcoal furnace renders it possible to use sodium carbonate for making the fusion, thus avoiding the use of the very hygroscopic potassium carbonate. The furnace may also be found convenient for other experiments where an intense heat is required.

This investigation was undertaken for the purpose of finding some simple means for the *direct* determination of water in refractory minerals, and the results that have been given indicate that the methods are accurate. The closed tube method is almost as simple as the determination by loss on ignition, and a direct weighing of the water is always a satisfaction, since otherwise there is a possibility that some volatile constituent may go off and render the result inaccurate. For example the sample of talc that was used in the previous experiments, and found to contain 4·42 per cent of water, lost 4·87 per cent by direct ignition the high result being due to the presence of a little fluorine and the liberation of acid water probably carrying some silica.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, New Haven, Conn., April, 1894.

* Tschermak's Min. Mitth., 1875, p. 214.
† Sitzb. der K. Akad. der Wiss., Wien, lxxvi, p. 51, 1877.

ART. VII.—*The Detection of Alkaline Perchlorates associated with Chlorides, Chlorates, and Nitrates;* by F. A. GOOCH and D. ALBERT KREIDER.

[Contributions from the Kent Chemical Laboratory of Yale College—XXXII.]

THOUGH perchloric acid in the free state is an exceedingly active body, its combinations with alkaline metals are, as is well known, so characterized by inertness toward ordinary reagents that in order to effect its detection it has been customary to place dependance either upon the insolubility of the potassium salt in alcohol, or upon tests for the corresponding chloride derived by ignition.

In experimenting at high temperatures upon mixtures of potassium perchlorate with salts of the halogens we have found it possible to effect the liberation of the halogen to a greater or less degree by the oxygen of the perchlorate, but the amount thus evolved has never been sufficiently complete or regular to warrant the application of the reaction to the quantitative determination of the perchlorate. In two parallel experiments, for example, a mixture of the double chloride of aluminum and sodium with 0·05 grm. of potassium perchlorate evolved in fusion in a tubulated flask (which was fitted by a ground joint to an inlet tube carrying a constant current of carbon dioxide and connected with Will and Varrentrapp absorption bulbs filled with a solution of potassium iodide), an amount of chlorine corresponding to 0·0482 grm. and 0·0460 grm. of the perchlorate. A similar experiment conducted in an atmosphere of hydrochloric acid gas and carbon dioxide in mixture yielded chlorine amounting to 0·0477 grm. of the perchlorate. Fusion of the perchlorate with cadmium iodide resulted in the liberation of much oxygen accompanying the iodine, and a mixture of zinc chloride with potassium iodide (melting at about 200° C.), yielded a large evolution of oxygen which was somewhat diminished but not wholly prevented when manganese chloride was included in the mixture. A series of 14 experiments in which mixtures of the perchlorate with potassium iodide were treated with meta-phosphoric acid (made by heating the syrupy ortho-acid to 360° C.) in an atmosphere of carbon dioxide showed deficits in the amounts of iodine evolved amounting to 1·7 per cent on the average between extremes of 3·6 per cent in excess and 7·7 per cent in deficiency, and these particular experiments doubtless point to a more complete utilization of the oxygen of the perchlorate than was actually attained owing to the inevitable partial de-

composition of hydriodic acid at the temperature necessary to effect the decomposition of the perchlorate.

We have, however, succeeded in developing a simple and delicate method of detecting perchlorates, and one which may be applied without great sacrifice in delicacy to mixtures of the perchlorates with chlorides, chlorates and nitrates. It is evident that for a rapid qualitative test conditions should be so chosen that the effect of atmospheric air shall not interfere with the certainty of the indication. Of the various salts which we have employed we choose by preference fused zinc chloride, chiefly because, while sufficiently energetic in its action upon the perchlorate, it does not, like manganese chloride or the double chloride of aluminum and sodium, evolve chlorine under the influence of ordinary air at the high temperature of the reaction.

In the experiments recorded in Table I varying portions of a solution of potassium perchlorate were evaporated to dryness in a test tube and fused with anhydrous zinc chloride. A trap made by cutting off an ordinary two-bulbed straight drying tube was hung with the larger end downward in the test tube, after moistening the interior of the bulbs with a solution of potassium iodide. The chlorine evolved during the heating was registered by the iodine set free from the iodide and subsequently washed with a little water from the trap and tested with starch emulsion.

TABLE I.

$KClO_4$ taken.	Indication by the starch test.
0·00100 grm.	Strong.
0·00050 "	"
0·00020 "	"
0·00010 "	"
0·00010 "	"
0·00005 "	Distinct.
0·00005 "	"
0·00003 "	Trace.
0·00003 "	None.
0·00001 "	"
0·00000 "	"

The test for 0·00005 grm. of potassium perchlorate is sure and distinct; and it is, of course, evident that the presence of a chloride in the original test can in no way interfere with the certainty of the indication. All substances, however, which yield chlorine by decomposition or by the action of the air must be removed or destroyed before the application of the test. We find by experiment that 0·1 grm. of potassium chlorate is completely broken up by treatment with 5 cm^3 of

the strongest hydrochloric acid and evaporation to dryness. Nitric acid does not yield so readily to the decomposing action of hydrochloric acid and may be detected in the residue after four similar treatments. To destroy nitrates, therefore, we followed the general plan of decomposition employed in a quantitative method for the determination of nitrates previously elaborated in this laboratory* and treated the dry substance to be tested with 2 cm^3 of a saturated solution of manganous chloride in the strongest hydrochloric acid. The liquid was evaporated to dryness, and the residue was again treated similarly with one or two cubic centimeters of strong hydrochloric acid. This method of decomposing the nitrate is peculiarly advantageous since the decomposing agent is itself an excellent indicator of the completeness of the work of removal. Two or three treatments serve to remove the nitrate entirely; but before proceeding with the test it is necessary to remove the manganese which has been introduced, inasmuch as manganese chloride will of itself evolve chlorine, by exchange for oxygen, when heated in air. Sodium carbonate in solution answers the purpose of removing the manganese (together with other interfering substances) and the filtrate from the precipitated manganous carbonate leaves on evaporation a residue, which, when treated with the anhydrous zinc chloride, gives indications for the perchlorate if it is present in appreciable amount. The results of a series of tests for potassium perchlorate associated with the chlorate and nitrate of the same element and recorded in the following table.

TABLE II.

$KClO_4$ taken. grm.	$KClO_3$ taken. grm.	KNO_3 taken. grm.	Treatment for the removal of chlorate and nitrate.	Indication of the perchlorate.
0·0005	----	----	By HCl	Strong.
0·0003	----	----	"	"
0·0002	----	----	"	Good.
0·0001	----	----	"	"
0·0001	----	----	"	Trace.
0·0005	0·1	0·1	By HCl + $MnCl_2$	Strong.
0·0003	0·1	0·1	" "	Good.
0·0003	0·1	0·1	" "	Good.
0·0002	0·1	0·1	" "	Trace.
0·0001	0·1	0·1	" "	Trace.
0·0000	0·1	0·1	" "	None.

It is plain that 0·0001 grm. of potassium perchlorate may be found with certainty when associated with 0·1 grm. of the nitrate or chlorate or both.

* Gooch and Gruener, this Journal, xliv, 117.

ART. VIII.—*The Upper Vicksburg Eocene and the Chattahoochee Miocene of Southwest Georgia and adjacent Florida;* by AUG. F. FOERSTE.

The Boundary Line between the Vicksburg Eocene and Chattahoochee Miocene in S. W. Georgia.

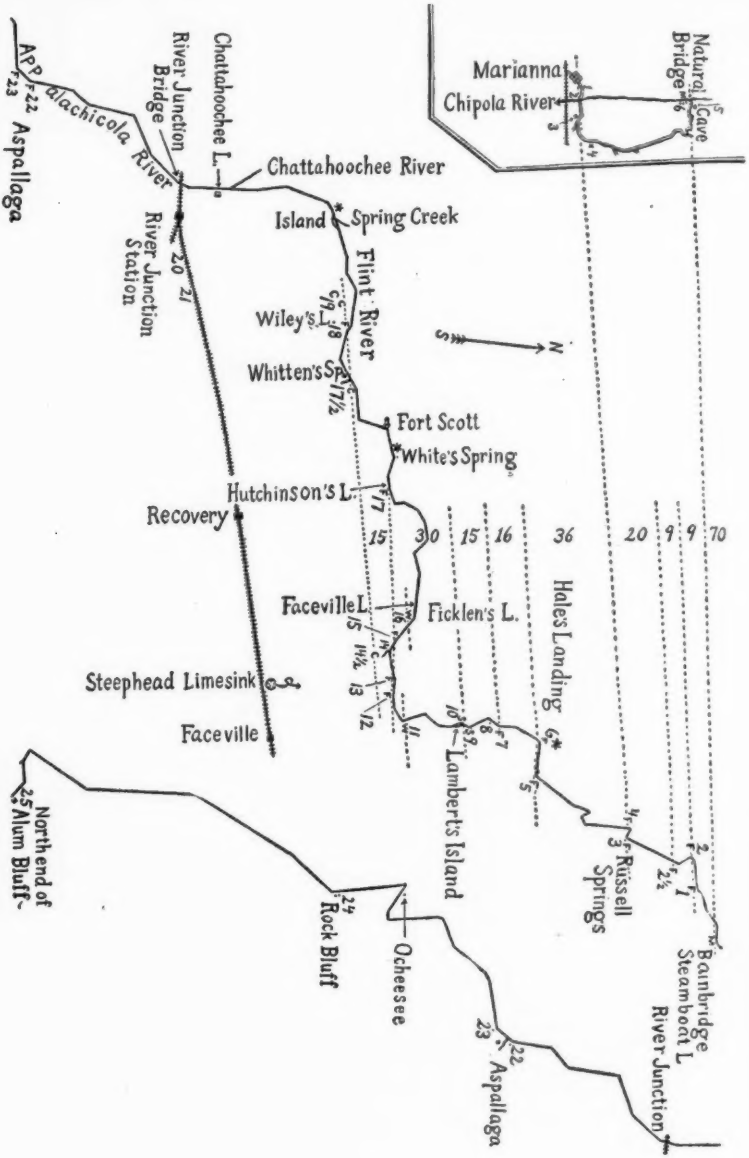
THE chief topographical feature of southwestern Georgia is the line of demarcation between the Eocene lowlands and the margin of the Miocene red clay plateau.* This line enters the State about 5 miles north of its southwest angle, follows the bluffs along the southern side of the Flint River for about 12 miles, continues in its direction across the country as far as Roseland Plantation, 4 miles south of Bainbridge, passes immediately to the north of Gasteropod Gully, Glenn's Well, and Powell's Limesink, the last locality being about 10 miles east of Bainbridge on the Thomasville road, and then turns more strongly toward the northeast, so as to leave the limesink and the Barrows plantation coral locality on the right. From its western extremity to Roseland Plantation this line is quite direct; it may be easily followed as far as Powell's limesink; beyond that point it seems to become more crooked and has so far not been accurately determined.

Method of Exposure of the Vicksburg.

On the northern margin of the red clay plateau the Vicksburg is found in limesinks, underlying the Chattahoochee, or Lower Miocene. In the lowlands extending from the plateau to the Flint River it occurs in the bottom of wells. Away from the river, very few surface exposures, which are evidently *in situ*, occur. Along the Flint River large blocks of siliceous Vicksburg rock are fairly abundant but it is evident that the greater part are only residual remains of the Vicksburg; the softer limestones and marls have disappeared or gone over into red clays, and in most places only the broken fragments of the silicified beds remain, let down as huge bowlders and slabs to the present limit of degradation,—the lower levels of the river banks.

At first it seemed impossible to use these blocks for stratigraphical purposes. However, during a trip down the Flint River, with Prof. Raphael Pumpelly, the localities where the bowlders occur were carefully platted on a sketch map of the river, and it became evident that these bowlders were distrib-

* That part of the plateau region lying south of Bainbridge is more fully described by Prof. Raphael Pumpelly, in this Journal, Dec., 1893, page 445.


Marianna
Chipola River
Natural Bridge
Cave
Chattahoochee River
Chattahoochee L.
River Junction Bridge
Apalachicola River
Aspallaga
Island
Spring Creek
Flint River
River Junction Station
Wiley's
Whitten's Sp.
Fort Scott
White's Spring
Hutchinson's L.
Recovery
Faceville L.
Ficklen's L.
Hale's Landing
Steephead Limesink
Faceville
Lambert's Island
Russell Springs
Bainbridge Steamboat L.
River Junction
Aspallaga
Ocheesee
Rock Bluff
Northend of Alum Bluff
S
N
15
30
15
16
36
20
9
9
70

uted along lines running a little north of east. These lines occurred at such distances apart as to suggest that they represented so many distinct silicified layers in the original Vicksburg section of this part of Georgia. It also seemed evident that even if not precisely *in situ* the lowering of these bowlders from their original position must have been of such moderate extent and must have taken place so gradually as not to confuse their position in the stratigraphic scale, otherwise the decidedly east and west character of these lines would have been marred, and there would have been a more evident commingling of rocks of different lithological character. Since these lines of bowlders furnish information as to the strike of rocks and promise to be of considerable value in working out the stratigraphy of the Vicksburg Eocene of this region the sketch map is here reproduced. It evidently offers materials for a section in which the soft white limestones are omitted and in which only the harder silicified courses appear.

Description of the Flint River section. Vicksburg.

(*a*) The base of the section so far examined is offered by a locality six miles north of Bainbridge, on the west side of the river, near a country graveyard east of the road in the woods. Here massive ledges of siliceous rock of unusual thickness occur, the section being at least 15 feet thick, the usual thickness of siliceous layers elsewhere being but 2 to 4 feet. This layer apparently occurs also on the east side of the river at various localities; in one case, one and a half miles east of the river, between the river road and the western Camilla road, near some plantation houses about 7 miles from Bainbridge; also still farther east, on the eastern or old Camilla road leading to the limesink, about 8 miles from Bainbridge. This horizon furnishes many fossils though chiefly in the form of casts, and almost all identical with forms found at Bainbridge and at Russell Springs. Owing to its massiveness this layer is more apt to occur as surface exposures and could probably be traced much farther east and west than has been done, thus offering an important datum line in the Vicksburg.

(*b*) Above this occurs the Bainbridge marl, exposed along the southern side of the river, at water level, east and west of the steamboat landing at Bainbridge. It is very calcareous, and contains many fossils, imbedded in a matrix composed of innumerable quantities of foraminifera, chiefly Orbitoides in all the various stages of development, the finer cementing material having in most cases disappeared to such an extent, owing to percolating waters, that it is possible to secure many shells and sea-urchins

free from the surrounding rock.* This bed is the best collecting ground for Vicksburg fossils so far found in southwest Georgia; the variety and state of preservation of the fossils is excellent, and the bed has also decided value for purposes of correlation since nothing similar has so far been found elsewhere in the Vicksburg in southwest Georgia. It is with this layer that the bed dug up in the ditch near the Natural bridge on the Chipola River north of Marianna in Florida, is correlated. Immediately above the Bainbridge marl occur one or two silicified layers, represented at the Natural Bridge north of Marianna by the more massive silicified layer forming the top and the walls of the natural cave, a short distance east of the *bridge*, locality 5.

(*c*) The next silicified layer occurs at localities 1 and 2. The first presents many sponges, Orbitoides, simple corals, Hinnites, Pectunculus, including also a small, radiately strongly ribbed species of this genus, Cytherea, Cerithium Mariannensis, Melongena, and Mitra. At the second, Pectunculus, Pecten and Cytherea were found. It is possible that this layer is also represented by the massive silicified limestone at the cave near the Natural Bridge north of Marianna. At 2½ silicified rock occurs, containing many sponges, some massive corals, Pecten, and Cassidaria (Sconsia). Whether this forms a distinct layer or not, is undetermined.

(*d*) The next silicified layer is represented by localities, 3 and 4. The first of these is near Russell Springs, a picturesque limesink, surrounded by steep banks, filled with water, in which cypress trees grow abundantly. Numerous fossils were found here, the species being usually the same as those seen along the river at Bainbridge, either in the marl or in the silicified layers immediately above. At 4 there were many sponges, simple corals, Pecten, Hinnites, Pectunculus and Ampullina. This bed is probably represented at Marianna by the silicified beds above the level of water at the bridge across the Chipola River east of the town, locality 2.

(*e*) The next silicified layer is exhibited at localities 5 and 6. At 5, numerous small bowlders are carted together at the top of the bank; they contain Orbitoides, Lunulites, a Pecten with 7 or 8 broad ribs, numerous specimens of *Turritella*, the precursor of *T. variabilis* Conrad. This species occurs in the Vicksburg, Chattahoochee, Chipola, and Chesapeake of S.W. Georgia, and western Florida. It may be characterized as having a spiral rib a little posterior to the anterior suture, another rib a little posterior to the median line, a deep groove or con-

* Loc. cit., p. 445, with *Echinocyamus parvus, Scutella Lyelli, Pecten Poulsoni*, and unknown species of Amusium, Pectunculus, and Cerithium as frequent fossils.

striction between these ribs, and a slope from the last named rib to the posterior suture. By addition of other spirals both ribs assume later the form of elevated bands defined by two spirals each. By the adding of striæ in the groove and on the posterior slope the later formed whorls may become heavily ornamented. The Eocene form of this shell occurs at 5, two miles east of Marianna at the quarry, 4, and six miles north of Bainbridge on the west side of the Flint River, at the graveyard locality. At locality 5 at the river's edge is silicified rock more evidently in place and resembling that at locality 6. At 6, the silicified layer is well exposed and contains Orbitoides, sponges, massive and also simple corals, Ostrea, Pecten, a rock-boring lamellibranch, Strombus, and two species of Cerithium. A little farther up the river the soft white limestone which once filled in at least a part of the intervals between the various silicified layers, is still visible; it occupies a slightly lower level and contains Orbitoides.

(*f*) At 7 occurred a silicified bed containing chiefly sponges, but also many massive corals, a concentrically striated Modiola 85^{mm} long, Cytherea, Ampullina, and the two species of Cerithium above mentioned. The layer bears evidently close faunal and lithological relations to layer *e*, but this does not necessarily imply the identity of the layers. At 8 a single large bowlder contains chiefly sponges, but also a stray Cytherea, and a large massive coral.

(*g*) The next layer is exposed at 9 and 10 and on Lambert's island. It is strongly characterized by being the only rock along the Flint River section here given, which look more like a sandstone than an ordinary silicified layer. At 9 it is more like sandstone and only a few small stray bowlders contained fossils, Pectunculus and Pectens. At 10 the more silicified material is full of Pectunculus and Pecten, and a stray astræiform coral was seen. At 11 and 16 the soft white limestone, which formed such a large part of the upper Eocene section, but which is usually worn away between the silicified layers along the river banks, is exposed. At 11 it contains Orbitoides and at 16 are found Orbitoides and a few Pectens.

(*h*) The highest silicified layer in the Vicksburg section is that found at 12, 13, 15, and 17. The deviation from parallelism between this line and the Chattahoochee outcrops is probably due to the difficulties in platting a river from a skiff. At 12 sponges are common and Pectens seem frequent. At 13, many Orbitoides and a sea-urchin occur. At 15, were found many concretionary looking sponges and a few Pectens. At 17 were abundant Orbitoides and stray Pectens.

Thickness of the Flint River section.

The data for an exact determination of the dip the Eocene southwards are not yet secured. Prof. Raphael Pumpelly determined the level of the base of the Chattahoochee to be 102 feet above the sea at Glenn's Well, and 155 feet above the sea in Powell's limesink. The first of these localities is 5 miles from the river almost directly east of Russell Springs, and 4 miles south of Bainbridge on the Coon-bottom road. The base of the Chattahoochee outcrops again along the Flint River at the localities 14½, 17½, 18, and 19, but little above the water's edge. The river localities are about 6 miles south of the line of strike of the Chattahoochee at Glenn's Well. The precise level of the river where the Chattahoochee outcrops is not known, but a dip of 13 feet to the mile is considered at the present state of our knowledge to be amply sufficient to account for the facts.* At this rate the thickness of the Vicksburg section, from the Bainbridge marl to the Chattahoochee overlying it, would be 150 feet; the massive siliceous bed along the Flint River 6 miles north of Bainbridge would be 70 feet below the Bainbridge marl, making a total section of 220 feet, with the possibility that these thicknesses are overestimated. The figures on the accompanying sketch map will sufficiently indicate the intervals between the different silicified layers.

Chief characteristics of the Flint River section.

The chief characteristics of the Flint River section are: 1, the comparatively great thickness of the silicified beds 6 miles north of Bainbridge; 2, the Bainbridge marl with its abundant echinoids and other fossils loosely enclosed in a cement of which Orbitoides forms the main element; 3, the long interval between layers *d* and *e*; 4, the more sandy character of the layer *g* at Lambert's Island; 5, the great amount of soft white limestone in the upper part of the section, interrupted only by the siliceous layer *h*.

Correlation of the Marianna section with layers b to e of the Flint River section.

In a corner of the sketch map the Marianna section has been introduced. It shows the road leaving Marianna on the east, crossing the Chipola River, and then turning northwards, for several miles, after which a road through fields finds its irregular path to the Natural Bridge. It is better to secure a native as a guide here. The section was

* Loc. cit., page 445.

visited on a trip with Prof. Pumpelly and Mr. Alfred Brooks. At the Natural Bridge, about 3 miles north of Marianna, the Chipola River disappears under the ground, reappearing farther on. At present a ditch or canal (6) diverts a part of the water at this point, securing a partial surface flow. During the cutting of the ditch numerous echinoids and other fossils characteristic of the Bainbridge marl bed, in a similar state of preservation, and enclosed by a similar cement of Orbitoides shells as at Bainbridge, were unearthed. East of this ditch, perhaps a quarter of a mile distant, is a cave (5), the upper walls of which are composed of a hard siliceous rock, containing abundant Orbitoides. There is so much rock exposed at this cave that it probably represents not only the siliceous layers found above the marl at Bainbridge, but also the siliceous bed *c* (localities 1 and 2), and the siliceous bed at locality 2½ along the Flint River. At the edge of the river, where the road running east from Marianna crosses the Chipola (2), there is considerable siliceous rock which from its distance south of the marl bed should be correlated with layer *d*, the Russell Springs layer of the Flint River section. Above this layer is a whitish, porous, soft, pulverulent, silico-calcareous rock, 20 feet or more in thickness (1, near 2, 3, 4). This should correspond to the rock once filling the interval between layers *d* and *e* of the Flint River section though nothing similar has been noted there. It is well exposed between Marianna and the bridge crossing the Chipola (1, near 2), where a very thin form of Orbitoides, and a Pecten are very common; again, about one and an eighth miles east of Marianna, in a quarry south of the road (3) where in addition to a few of the fossils just named, a small shark's tooth with very broad base, and very short triangular tip was found; finally about 2 miles from Marianna, on either side of the road but especially in an old quarry east of the road (4) where—in addition to the thin Orbitoides and the Pecten—species of Lunulites, Cardium, Cerithium, Turritella, and other fossils were found. The same white pulverulent rock is found southeast of Marianna, along the north side of the railroad, containing the thin Orbitoides, but here a few siliceous beds are intercalated in the pulverulent rock series. At first sight this rock presents lithologically an appearance similar to many middle Chattahoochee exposures, such as those along the railroad east of Chattahoochee, or the exposures east of the landing of the same name, but the base of the Chattahoochee no doubt does not crop out for several miles down the Chipola River.

Strike of the Vicksburg indicated by the Bainbridge bed exposures.

The Bainbridge marl exposure at the Natural Bridge, 3 miles north of Marianna in Florida, lies about 40 miles west of Bainbridge in Georgia, or to be more precise, about S. 78 W. and this is so far the nearest approximation to an estimate of a strike for any great distance in southwest Georgia and adjacent Florida. Judging from this line of strike the Bainbridge marl should be exposed somewhere in the vicinity of Miriam's Landing on the Chattahoochee River. The line of outcrop of the Chattahoochee curves strongly northwards east of Bainbridge, but until the observations over that part of the area are accurate enough to determine the dip, and the elevation of localities above the sea, and from these data to calculate the real strike, it is only possible to say that strike of the Chattahoochee is probably very soon changed to strongly towards the northeast on passing Bainbridge, since the nearest point where the position of this horizon can again be approximately determined is near House Creek on the Ocmulgee.

Correlation of various exposures in Decatur County, Georgia, with the soft white limestone at the top of the Vicksburg, above layer g of the Flint River section, and the base of the Chattahoochee.

1. *The limesink on the Camilla road.*—Fifteen and a half miles northeast of Bainbridge, on the old Bainbridge-Camilla road, and west of the Whigham-Camilla road, is a very fine limesink, well known in the adjoining counties. On a trip with Mr. Alfred Brooks a short examination of the same was made. The depth of the sink was estimated at, at least, 45 feet. A rapid stream about 6 feet broad enters the sink on one side, where the walls are vertical, and at the base disappears again under a recess beneath the cliff. Elsewhere the walls of the limesink are very steep but can be descended. At the bottom the well known Orbitoides, Pectens, and other remains of the Vicksburg Eocene were discovered. The general mass of the rock is whitish and soft, turning to more drab and becoming more hard at certain levels, especially towards the top. The rock over which the stream flows before plunging into the limesink is lithologically dissimilar, light brown, soft, porous, argillaceous with fossils only as casts. Although fossils were not rare, most of them were poorly preserved, and while their general aspect was that of Chattahoochee fossils it would require more extended study to assert their position, since many of the forms appeared new to us, we having collected so far only in the more southern exposures

of this group. The finding of *Orbitolites Floridana* however strengthened us in our belief that this was the Chattahoochee. Three miles north of the limesink is a natural curiosity known as the Blowing Cave. One mile east of the same, 18½ miles northeast of Bainbridge, and 7½ miles north of Whigham on the Whigham-Camilla road, is Barrow's plantation house.* Here Prof. Raphael Pumpelly found abundant masses of coral, identical in species with those to be mentioned later as occurring in the basal Chattahoochee, along the Flint River. Their occurrence here strengthens the view that the upper layer at the limesink is also Chattahoochee. The coral layer is known to be present only at a few localities in the basal Chattahoochee in S.W. Georgia.

2. *Powell's limesink*, 7 miles east of Bainbridge, on the Thomasville road, and about 4 miles northeast of Climax has steeply inclined earth covered walls, at the base of which the Chattahoochee limestone is exposed. This is white or grayish white in color, and rather soft in texture, excepting in certain layers, especially at the very base of the Chattahoochee, where the rock is compact and hard and contains a few fossils similar to those at Glenn's Well and at Wiley's Bluff. The Vicksburg rock immediately below is very soft, and white, and forms a part of an almost vertical descent into a sort of well or shaft. Towards the top it contains characteristic Vicksburg echinoids and Pectens, such as are found at Bainbridge. At the base of this shaft were found the concretionary sponges, Orbitoides, and Pecten. Towards one side of the shaft an opening led down gradually into a sort of low long cave, followed by a stream of water. Here a hard rock corresponding perhaps to layer *h* of the Flint River section was noticed, below which was more soft white rock, with Orbitoides, Pecten, a long lamellibranch shell digging tubes 6 inches long into the rock, the bases and lower sides of these tubes being usually occupied by a thin layer of some astræiform coral, Cypræa, and Cerithium Mariannensis. Towards the lower point visited the rock became harder and light brown in color.

3. At *Glenn's Well*, 4 miles south of Bainbridge on the Coon Bottom road, there is only a thin layer of the Chattahoochee, the fossiliferous part of which is a white, siliceous, very friable rock. Only the very top of the Eocene is shown. It is hard, partly silicified, brown in color, and contains Orbitoides, Cerithium Mariannensis, a stray sea-urchin, and other fossils.

* W. H. Dall, Correlation Papers Neocene, under Georgia. Loc. cit., page 447.

4. *Sweigert's Well*, 2 miles north of the Thomasville road, and 3 miles northwest of Powell's limesink, shows the same brownish more silicified phase, and contains the so-called concretionary sponges, Orbitoides, Pecten, Lucina, Xenophora, and Cerithium Mariannensis.

*The Coral layer at the base of the Chattahoochee.**

On our trip down the Flint River, Prof. Pumpelly discovered at locality 14, on the bank, at the mouth of a small creek, a great heap of bowlder, containing, among other things, large massive corals. On a subsequent trip with Mr. Alfred Brooks I traced these bowlders to locality 14, where the stream cutting down the north slope of a long high ridge, exposes the Chattahoochee at the base. In the soft whitish rock near the base of the hill the massive corals occur scattered around very irregularly through the white limestone. When *in situ*, they do not command special attention on account of their numbers, but in the beds of the stream they have accumulated to such an extent, owing to their greater resistance to disintegration, that they at once attract the observer's eye. The rock below with similar lithological features, that is, soft and very white, with few fossils except the concretionary springs, is the Vicksburg.

On the trip with Mr. Alfred Brooks, abundant massive coral blocks were found in the river bed at locality 17½. On the trip with Prof. Pumpelly, the massive corals were found along a wood road leading southwest from Wiley's Landing. They were not numerous but at some localities more were found than at others. Their occurrence was beneath the brecciated limestone considered the base of the Chattahoochee. Taken together, these localities would indicate a sort of mild coral bank extending about east and west along the northern face of the present Chattahoochee outcrop along the Flint River. The coral locality on Barrows Plantation has already been mentioned. It suggests the presence there of the base of the Chattahoochee.

The Chattahoochee.

Wiley's Landing bed.—For paleontological purposes the base of the Chattahoochee can be studied at Wiley's Landing, or locality 18. At the river's edge are found pieces of a peculiar white limestone, irregularly cracked, breaking with a conchoidal fracture, usually quite hard, but also found with the exposed surfaces soft and friable, contain-

* Loc. cit., page 447.

ing fossils mostly in the form of casts. Lithologically this rock strongly resembles the upper Vicksburg. It occurs also at locality 14, among the blocks heaped up along the river bank. The situation and lithological character of these blocks seemed to be that of the upper Vicksburg, and the fossils were not satisfactorily identified but seemed to have a Chattahoochee facies. Above this level are a few silicified courses, and then in turn comes a massive bed of a grayish-white rock, quite firm, but readily broken by a hammer, in which occur those fossils which have been recognized at a number of localities as constituting the basal fauna of the Chattahoochee. This bed, which I shall call the *Wiley's Landing Bed*, may have a thickness of 20 feet, but at the Landing the actually exposed part hardly rises that far above the river level. Toward the base of this Wiley's Landing bed the rock is brecciated, the cracks being filled in with calcite of almost the same color and constituency. The coral blocks at locality 19, although loose in the stream beds, always occurred below this level of brecciation, and so were considered as of a lower horizon. The brecciated rock is as a rule unfossiliferous. It occurs also near the stream leading out of the sink at Steep Head, west of Faceville, northwards towards the Flint River, perhaps an eighth of a mile north of the sink on the west side of the stream. Also at Griffin's Creek, four and a half miles south of Bainbridge. Reasons are given later on for believing that the last locality does not represent the same horizon.

Chattahoochee bed proper.—Next in order comes the *Chattahoochee bed*, well exposed near the (Old) Chattahoochee Landing. This locality represents a southing of about three and a half miles from that of Wiley's Landing. Its main element is a peculiar gray limestone tinged with yellow, soft, friable, readily reduced to powder. At the Landing the fossils occurred chiefly at a level only a few feet above the river level, but the friable rock extends to a height of 30 feet above the river level. Rock of the same lithological character, and having a closely allied fauna occurs about a mile and a half east of the River Junction Bridge (called Chattahoochee Landing by W. H. Dall), along the railroad which crosses the river three-fourths of a mile below (Old) Chattahoochee Landing. Here the fossils occur at a higher level than at the Old Landing, and it is to be noted that the brecciated bed along the stream leading south from Steep Head, also seems to have a somewhat higher position than would be expected from its position at Wiley's Landing.

Thickness of Chattahoochee bed proper.—The position of the fossiliferous bed at the Old Chattahoochee Landing is estimated as being at least 40 feet above the base of the Chatta-

hoochee as shown at Wiley's Landing. The top of the friable limestone of Old Chattahoochee would then reach a level of about 65 feet above the base, and the lowest exposure at Aspallaga Bluff about five and a half miles farther south, would be at least 80 feet above the base of the Chattahoochee. The main body of the rock exposed at Aspallaga is evidently closely related to the localities just mentioned farther north. The soft friable rock, here containing shark's teeth, and other teeth which we judged to be reptilian, also apparently fish bones, was abundantly represented. Harder courses contain the ordinary middle Chattahoochee fauna. More siliceous layers occur, but their presence is also familiar along the railroad exposures half a mile northeast of Chattahoochee Junction above mentioned. The top of these Chattahoochee limestones rises according to Dall and Stanley-Brown about 50 feet above the river level. This would place it at least 130 feet above the level of the base of the Chattahoochee, and would give the Chattahoochee bed itself a total thickness of at least 100 feet.

Griffin bed and Aspallaga clays.—The *Aspallaga clays* with its Oysters and Pectens we did not see. This is unfortunate since we found a hard rock full of Orbitolites and a few other shells at a level which seemed to us, judged only by the eye and the effort it required to reach the locality, to be much higher than 50 feet above the river level. This rock is lithologically and paleontologically identical with that at Griffin's Creek and seems to promise considerable as a valuable means of correlating various horizons. I shall call it the *Griffin bed*, and believe its location to be at the top of the Chattahoochee bed, and therefore about 50 feet above the river level or a hundred and thirty feet above the base of the Chattahoochee. Above the Griffin bed occur the Aspallaga clays.

*Griffin's Creek locality.**—At the Griffin's Creek locality, four and a half miles south of Bainbridge, on the west side of the road, about half a mile west of Griffin's house, and a little north of a plantation shed occurs an exposure of interest in this connection. The lowest exposure at this locality is a brecciated limestone, about 2 feet thick. Above this lies the peculiar Griffin bed, cavernous on account of the dissolution of the many gasteropod shells once contained in them, and still containing many specimens of Orbitolites. This bed may possibly be 6 to 8 feet thick at this point. In the calcareous clay, often already deep red, or clayey brown owing to decomposition, there are found the same Anomia and apparently the same Pecten as in the Aspallaga clays of Rock Bluff. This would place the Griffin Creek bed at the junction of the

* Loc. cit., page 447.

Chattahoochee bed and the Aspallaga clays, and would suggest that the brecciated limestone just below either represents a second horizon of brecciation, or that there must once have been a great Eocene island in this part of the country and that at the Griffin Creek locality the elevation was such that there was still a chance for shore work, at a time just preceding the deposition of the two beds of later age at that locality.

The elevation at Griffin's Creek is 180 feet above the sea; at Glenn's Well, 2½ miles southward, the base of the Chattahoochee is 102 feet above the sea level. This would give the Griffin bed at this point an elevation of 80 feet above the base of the Chattahoochee, instead of 130 feet, as given in the Flint River section. This may possibly indicate a thinning out of the Chattahoochee section towards the eastward.

Powell's limesink lies 7 miles east of Bainbridge. The elevation of the base of the Chattahoochee is there 155 feet above the sea level. So little has yet been done to trace out anticlinal axes, strikes and dips of these flat-lying rocks that it would be difficult to affirm much from known data. The more northern location of this locality and a low westward as well as southern dip might account in part for its greater elevation above sea level. But the belief in an uneven base of the Chattahoochee seemed the most natural at the time field observations were still being made.*

The *Aspallaga clays*, not seen by us at the type locality, are well exposed at Rock Bluff. According to Dall and Stanley Brown† the marl has here a thickness of 67 feet. Rock Bluff representing a southing of about four and a third miles from Aspallaga Bluff, the base of the Aspallaga clays being 50 feet above the river at Aspallaga Bluff,† and 12 feet above at Rock Bluff,† the dip of the rocks may be variously estimated at from 9 to 11 feet per mile southwards, according to the supposed fall in the river level. Alum Bluff lies about 6⅓ miles south of Rock Bluff, measuring across the supposed strike of the Miocene. At this rate it seems as though the Aspallaga clays must thin out more or less southwards, since otherwise they should be at about water level or slightly above, at Alum Bluff. No doubt they occur at no great distance below water level. At this rate the Chipola bed must be rather thin. Its base may be estimated as occupying a position at least 160 feet above the level of the base of the Chattahoochee as shown at Wiley's Landing. The question as to whether the Aspallaga clays belong in the Chattahoochee or in the Chipola will no doubt be settled as investigations go on. The Anomia in these clays was found in the Wiley's Landing basal Chattahoochee, as well as at the Griffins' Creek locality, but was not

* p. 447. † Cenozoic Geology along the Appalachicola River, p. 155.

seen in the Chipola around Bainbridge, at Alum Bluff, nor along the Chipola River. The oyster so common in these clays was also found at Wiley's Landing and the Griffin localities, but not in the Chipola. For that reason I am still inclined to consider the Aspallaga clays as the top of the Chattahoochee series, at least, until further collecting shows an assemblage of true Chipola fossils in these clays. Other collectors may have already secured this desired additional material.

The writer is under special obligations to Mr. Dall and Stanley-Brown, for more precise determinations of the thickness of the various Chattahoochee beds, and to Prof. Raphael Pumpelly and Mr. Alfred Brooks for the opportunity to accompany them during their various trips down the river and elsewhere, which made it possible to collect the material for these notes and utilize many of their observations. His obligations to various publications need not be expressed in detail since these publications are too recent to require recalling to memory and are sufficiently indicated in the publications of Mr. Dall.

On the accompanying sketch map* the course of the Flint and Appalachicola Rivers has been represented in two sections. The Marianna region is mapped and introduced into a corner of the page, so as to show its relations to the Flint River section. All of the mapping being the result of traverse work is sure to have its faults, but being done with considerable care, is certain to be vastly superior to the ordinary maps which fall in the traveler's hands. The railroad east of the River Junction station is only approximately located, so that the position of the Steephead Limesink is not accurately determined, excepting as regards its location west of Faceville. For the Eocene a slope of 13 feet to the mile is assumed, for the Chattahoochee, one of 9 feet to the mile. The question of dip still awaits more detailed study. Localities starred are suitable for camping when traveling in skiffs.

Art. IX.—*On Gabbros in the Southwestern Adirondack Region;* by C. H. Smyth, Jr.

The presence of large areas of anorthosite in the Adirondack region has long been known, although the igneous nature of the rocks has not been universally recognized. In a recent paper Professor J. F. Kemp† has described extensive developments of gabbro in the vicinity of Lake Champlain, which

* See page 42.

† Gabbros on the Western Shore of Lake Champlain, Bull. Geol. Soc. America, v, p. 213.

are connected with the anorthosites previously known. During the past summer the writer examined a group of related rocks, which, from their character, mode of occurrence and location, seem to merit description.

The locality is in the southwestern corner of Hamilton County, between the hamlet of Morehouseville and Wilmurt Lake, which lie about five miles apart on opposite sides of the valley of the West Canada Creek. The hills bordering the valley consist chiefly of two varieties of gneiss. One is a rather acid rock composed largely of quartz and orthoclase, with a peculiar spindle structure, giving to weathered surfaces the appearance of partially decayed wood. The second variety is of a brownish tint, which may be only superficial, and contains hornblende in some quantity. Its foliation is of the ordinary type and sometimes shows much crumpling. A third variety of gneiss, usually nearly black, coarse grained, often massive, and containing large lumps of garnet, is present in more limited amount. The relations subsisting between these gneisses have not as yet been determined.

The rocks with which the present paper is chiefly concerned are seen at several points between Wilmurt Lake and the creek below, the first outcrop being about a mile and a half down the road from the lake, and several others appearing at various points within the next mile. Then there is a break and no further outcrops appear till the village is reached. This break is doubtless simply the result of the covering of exposures by heavy stream deposits. The outcrops show a dark, fine grained rock, forming irregular patches in the gneiss, with the line of demarcation between the two very distinct. These patches often have a tendency toward rectangular outline, and may be nearly equilateral, or elongated into a dike-like form. Their extent is usually limited to a few yards or rods. The same rock occurs in what might be taken for an interbedded layer in the gneiss, some fifteen feet thick and dipping 10° south. At Morehouseville a coarser variety constitutes a knoll three or four acres in extent.

The true nature of the rock is best shown, so far as field relations are concerned, in the small patches. It is seen to be entirely different from the surrounding gneiss in composition and structure; it cuts directly across the foliation of the gneiss and the passage between them is as abrupt as possible; occasionally fragments of the gneiss are included in it; and the zone of contact between the two rocks is marked by a narrow band differing in aspect from either rock and evidently the result of contact metamorphism. From these facts it is clear that the dark patches are intrusions in the gneiss, the bed-like mass being an intrusive sheet. The large body of rock at

Morehouseville gives only limited indications of its relations to the gneisses and the determination of its intrusive character is based upon its composition and structure and resemblance to the rocks of the smaller patches, rather than upon its mode of occurrence. This being the case, the character of the rock from the undoubted intrusions will be first considered.

Specimens from these outcrops show variations in color from very dark blue-gray, to a lighter gray with brownish tinge. The grain is fine and even, with little variation from point to point. There are, however, decided differences in the structure of the rock at different outcrops, as in some it is almost completely massive, while in others it is distinctly gneissoid. In every case the foliation is parallel to the foliation of the enclosing gneiss, and both in the field and under the microscope shows plainly that it is a result of pressure and not a flow structure. Weathering produces a light brown crust which has not been found of any great thickness, but which greatly obscures the superficial difference between the intrusives and the surrounding gneisses. Differential weathering has not proceeded sufficiently far since glaciation to cause any marked difference in elevation between the two rocks, but there is often a slight projection of the intrusive patches above the gneiss. Jointing is more perfectly developed in the former than in the latter, giving an appearance like that of many dikes of diabase and related rocks.

The darker variety of the rock very strongly resembles some of the finer grained specimens of the Baltimore hypersthene gabbro described by Professor G. H. Williams.* In fact this resemblance is so strong that it is sometimes difficult to distinguish from each other specimens from the two localities. The same resemblance exists somewhat in the composition and structure of the rocks as seen under the microscope, but in a less marked degree. Sections of the Wilmurt rock show a holocrystalline granular aggregate of plagioclase, hypersthene, monoclynic pyroxene, hornblende, a little biotite, and magnetite. None of these minerals have crystal outlines, being in irregular grains which range, as a rule, from ·1 to ·5^{mm} in diameter. A rather conspicuous feature is the absence of apatite, which is seen only rarely and in very small quantity. In a single specimen several grains of garnet are shown. Variations in the rock result from the different proportions of constituents present, and, in less degree, from differences of structure. In nearly all specimens the minerals are extremely fresh, showing almost no effects of weathering.

* The Gabbros and Associated Hornblende Rocks occurring in the neighborhood of Baltimore, Md. U. S. G. S., Bull. 28.

The mineral composition and structure are characteristic of the gabbro family, but the variation in relative amounts of the constituents in different masses makes it difficult to include them all under one minor subdivision of the family. In the majority of cases hypersthene is the prevailing ferro-magnesian constituent, making the rock norite; but in other examples hypersthene is subordinate to monoclinic pyroxene, so that it must be classed as hypersthene gabbro. Less often hornblende exceeds the pyroxene in quantity, the rock thus approaching diorite in composition. In a single specimen hornblende entirely replaces pyroxene, the specimen being taken from near the edge of a small patch having the normal composition throughout most of its extent. In general these dioritic phases are quite limited and appear to be more common towards the contact with the gneiss. In view of this variation in composition the rock may be best treated under the broad term gabbro, which will serve to include the important varieties, hypersthene gabbro and norite.

The least variable and most abundant constituent is the feldspar. It is conspicuously clear and free from all traces of the dust-like inclusion so common in the feldspar of the gabbros. The polysynthetic twinning of plagioclase is usually present and the extinction angles on the lamellæ, ranging from 22° to 28°, show that the feldspar is a basic bytownite. Unstriated sections of feldspar are common, but the chemical analysis of the rock indicates, by the small amount of K_2O, that little or no orthoclase can be present. Undulatory extinction is very pronounced in the feldspar, and is never lacking. Further effects of pressure are seen in bending and breaking of the lamellæ and sometimes in considerable granulation. In the most gneissoid specimens there is a limited alteration of feldspar to muscovite.

In perhaps two-thirds of the sections examined hypersthene is next to feldspar in order of abundance. In very rare instances it shows an approach to crystal form, but usually is extremely irregular in outline. It is fresh and clear, and perfectly free from the plate-like inclusions so common in the mineral. It shows the usual pleochroism quite strongly; a, pale red; b, pale yellow or colorless; c, light green; with very slight differences of absorption. It is distinguished from monoclinic pyroxene by this pleochroism, by its parallel extinction, and by its rather low double refraction, together with a high mean index.

The monoclinic pyroxene is pale green, or, in very thin sections, colorless, and has no pleochroism. Like the feldspar and hypersthene it contains no inclusions other than the older magnetite. The pinacoidal parting and fibrous structure of

diallage are lacking, the pyroxene being of augitic habit. The angle of extinction is about 40°. This pyroxene is often in somewhat larger grains than the hypersthene.

The hornblende, as already stated, is extremely variable in quantity, but is never entirely absent. It is compact, brown and strongly pleochroic; a light yellow, b deep brown, c dark greenish-brown, with the absorption $c > b > a$. It often contains small black inclusions, looking like magnetite. It is of considerable importance in making out the history of the gabbros and their relations to other rocks of the region to ascertain whether the hornblende is original or paramorphic. In favor of the latter supposition is the fact that the hornblende often partly encloses grains of pyroxene into which it seems to pass gradually. This intimate association is very common and often extremely marked. Paramorphism would, moreover, readily explain the increase of hornblende in some portions of the rock, even amounting to complete exclusion of pyroxene. On the other hand, the association of the hornblende and pyroxene clearly is often, if not always, the result of parallel growth and accidental juxtaposition. Further, in many cases the apparent gradual transition between the two is shown by careful observation to result from an approach to parallelism between the plane of their contact and the plane of the section. When this is not the case the line of junction of the two minerals is generally distinct and shows no indication of interpenetration. Then, too, the amount of hornblende in the rocks shows no close relation to the intensity of the mechanical force to which they have been subjected, as it is just as likely to be abundant in a massive rock as in one that is prominently gneissoid. Taking these points into consideration it seems probable that the hornblende is an original constituent of the gabbro and that the hornblendic phases of the rock are the result of local variations in the original magma, or of differences in the conditions of solidification.

Biotite is of very minor importance as a constituent of the gabbro, and need receive no special description. Its distribution is, however, of interest. Almost without exception in the finer gabbros the biotite occurs in close proximity to the plane of contact with the gneiss. The hornblende shows a tendency in this direction, but nothing like that of the biotite, which also tends to arrange itself parallel to the contact. The exceptions to this rule are few.

Magnetite is an unfailing and important constituent. It forms large irregular grains, plainly primary and in considerable quantity. Tested with H_2O_2 it shows the presence of some titanium, but as it is readily soluble in acids and strongly attracted by the magnet it must be a titaniferous magnetite rather than ilmenite.

The only macroscopic structural variations in the gabbros are differences in coarseness of grain and in degree of foliation. The grain as a rule remains nearly constant throughout any given body of the rock but varies somewhat in different patches. The hornblendic varieties are apt to be coarser than the normal rock, and as the hornblende is often more abundant toward the margins of the rock mass, these portions are sometimes decidedly coarser than the central portions, reversing the general rule in regard to intrusive rocks.

The gneissoid varieties when examined under the microscope show the effects of pressure in a greater or less amount of crushing of the minerals, besides the undulatory extinction, bending of twinning lamellæ, etc., which are seen in all sections. At the same time that the gneissoid structure becomes marked, the structure of the hypersthene undergoes a conspicuous modification. The mineral not only becomes shattered like the other constituents, but sends out long slender tongues into the surrounding feldspar. These tongues range from slight projections of the hypersthene to string-like extensions which radiate from a hypersthene core. In still more extreme cases this core is lacking and the hypersthene forms curious rosettes. It is often impossible to determine directly the nature of the mineral in the tongues, but it may be safely regarded as hypersthene as there is a complete gradation between them and the larger extensions plainly composed of this mineral. The larger tongues of hypersthene usually form a granophyric intergrowth with the feldspar presenting an appearance somewhat like that described by Bayley* in the augite of Lake Superior gabbros. It is impossible to deter-

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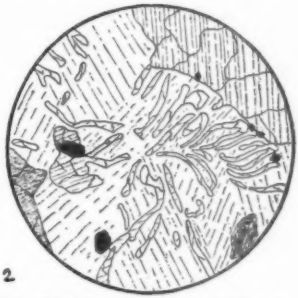

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FIG. 1.—Gabbro. Large piece of hypersthene sending out tongues into the surrounding feldspar. Diameter of field 0·7mm.

FIG. 2.—Gabbro. Separate tongues of hypersthene in feldspar. Diam. of field 0·4mm.

* W. S. Bayley. A Fibrous intergrowth of Augite and Plagioclase, resembling a reaction rim, in a Minnesota Gabbro, this Journal, III, xliii, p. 515.

mine whether the same regularity of orientation persists in the finer tongues, but such seems often to be the case. Again, the tongues wander irregularly through the feldspar, often extending between adjacent individuals. Figure 1 shows the first step toward this structure, figure 2 its more complete development though not approaching the fineness and complexity often seen. The extreme cases are often accompanied by an alteration of the feldspar to muscovite.

This stringing out of the hypersthene shows a most intimate connection with the development of gneissoid structure. When there are only slight traces of the latter structure the hypersthene occurs merely as irregular grains, but as soon as parallelism of constituents becomes marked the stringing out begins and becomes more and more conspicuous as the gneissoid structure increases. It seems a necessary inference that the phenomenon is a result of metamorphism but the rationale of the process is not clear, and it seems best to defer any attempt at explanation until more data are available.

The contact between the gabbro and the gneiss is quite distinct in hand specimens, being marked by a greenish gray band about 2^{mm} wide. Under the microscope the contact shows a narrow zone made up almost wholly of the pyroxenes with some biotite. Just within this band the gabbro consists chiefly of feldspar, and then gradually assumes its ordinary composition, though often containing an unusual amount of hornblende. The character of the contact zone is clearly due to the fact that the pyroxenes crystallized earlier than the feldspar and attached themselves to the solid face of the gneiss, leaving the adjacent layer of gabbro composed of nearly pure feldspar. The pyroxenes of the contact zone are almost completely altered to a green chloritic product, to which is due the color of this zone as seen in hand specimens. The gneiss shows no perceptible mineralogical changes at the contact, though its color is altered to a bluish gray tint.

The chemical composition of the gabbro is indicated by analysis I. The material analyzed was taken from a very fresh, massive specimen which showed under the microscope about the average proportions of minerals.

Analysis II gives the composition of a fresh specimen of the Baltimore gabbro described by Professor Williams* and III gives the results obtained by analyzing a mixture, in equal amounts, of specimens of this rock from twenty-three different localities.† The similarity in the results of the three analyses is striking and confirms the conclusion that the gabbro at Wilmurt is closely related to the Baltimore Rock.

* Op. cit., p. 37.

† Op. cit., p. 39.

	I.	II.	III.
SiO_2	46·85	44·10	46·85
Al_2O_3	18·00	24·86	19·72
F_2O_3	6·16	7·89	3·22
FeO	8·76	6·53	7·99
MgO	8·43	3·89	7·75
CaO	10·17	11·90	13·10
Na_2O	2·19	1·66	1·56
K_2O	0·09	0·24	0·09
H_2O	0·30	0·60	0·56
Totals	100·95	101·67	100·84
Sp. gr.	3·097	3·044	

The gabbro of the larger area at Morehouseville, as already stated, gives only slight indications of its intrusive character. The rock is decidedly coarser grained than that of the small patches, and on the weathered surfaces closely resembles the ordinary hornblende gneiss of the region. In thin sections it shows the same constituents as do the finer gabbros, with the addition of considerable apatite, while biotite is quite abundant throughout the entire mass. The percentage of ferro-magnesian minerals is smaller than in the other rocks, and the augite is decidedly more abundant than hypersthene making the rock a hypersthene gabbro rather than a norite. In structure it varies from completely massive to slightly gneissoid. No crushing is apparent in sections, the undulatory extinction is less marked than in the finer rocks, and there is no sign of the stringing out of the hypersthene.

It seems probable that the facts above stated may prove of value in working out the geology of this region by giving a clue to the origin of the black hornblende gneiss previously referred to. Very little has been done as yet along this line, but a brief outline of the more important observations thus far made may well be recorded in this connection, leaving the details for a later paper. The black gneiss was first seen on the shore of Big Rock Lake, about a mile and a half northeast of Wilmurt, where it lies between acid gneiss below and brown hornblende gneiss above. As the shores of the lake are thickly wooded it is impossible to make out the character of the contacts between the rocks. From this point the black gneiss extends nearly or quite continuously along the strike, till the head of Metcalf lake is reached, a distance of three or four miles. Beyond this point the country has not been examined. On the north shore of Metcalf lake there is a series of cliffs rising one above another in which the black gneiss is seen alternating with layers of brown gneiss, sometimes with a rather gradual transition between the two, but often with a

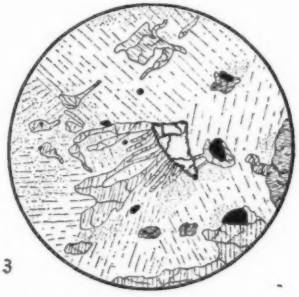
very sharp line of demarcation. As all the region is covered with dense forest it is almost impossible to get any more definite knowledge of the relations of the different rocks.

The black gneiss is coarse grained and usually more massive than the surrounding rocks, though by no means always so. Its most noticeable feature in the field is the presence of a great deal of garnet, ranging from small specks up to lumps two or three inches in diameter. Around the garnet there may generally be seen a narrow rim of dark green or black radiating plates. Freshly broken surfaces glisten with the brilliant luster of numerous cleavage faces of hornblende. From this normal type of the gneiss there are many variations. By a decrease in ferro-magnesian minerals it becomes light greenish-gray looking, very much like specimens of garnetiferous anorthosite from Essex County. In other cases the garnet disappears and the rock would then be taken for a basic gabbro. Rapid changes in the character of the rock often take place within the space of a few feet.

Sections of the gneiss show a mineral composition closely related to that of the gabbros. The feldspar is plagioclase, but in most sections is almost entirely changed to minute colorless scales, with the high double refraction, parallel extinction, absorption, and negative optical character of muscovite. In many sections this mineral wholly replaces plagioclase, but in others portions of the feldspar remain showing every stage of the alteration. Augite and hypersthene like that of the gabbro are abundant, together with hornblende of somewhat different character. This, though usually massive like the hornblende of the gabbro, differs from it in being pleochroic in green tints, sometimes with a decided bluish tone. It is intimately associated with both pyroxenes, and in such a way as to suggest that it may be derived from them, though positive proof of this is lacking. Magnetite and a little biotite make up the rest of the rock, aside from the garnet. The latter, as already stated, occurs abundantly in masses of varying size. It is sometimes perfectly clear, with a decided pink color and sharply defined, even boundary. In other cases its outline is very irregular with embayments and inclusions of the other constituents, particularly the hornblende and pyroxene.

The most conspicuous feature of the rock is its structure, due to the peculiar form of the hypersthene and hornblende. These two minerals, though often in irregular masses, show a decided tendency to extend out in radiating tongues, with a length often ten or twelve times their breadth. These tongues may start from any portion of the section, but commonly radiate from a mass of pyroxene or more particularly from garnet when it is present, thus giving rise to the radiating

bands seen around this mineral in hand specimens. The tongues are usually curved and when developed from several centers give a remarkably beautiful effect under the microscope, impossible to describe or to figure with accuracy. An attempt in the latter direction is shown in figure 4. This



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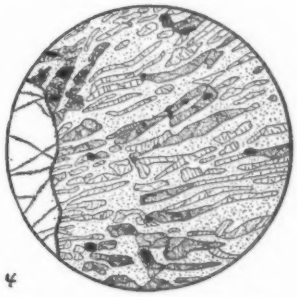

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FIG. 3—Gabbro. Tongues of hypersthene radiating from garnet. The feldspar somewhat altered. Diam. of field 0·7mm.

FIG. 4—Black gneiss. Tongues of hypersthene and hornblende radiating from garnet. Feldspar completely altered. Diam. of field 2mm.

structure is analogous in every respect to that described in the gneissoid gabbro, differing from it only in being on a larger scale, with all of the constituents coarser, and in the presence of tongues of hornblende as well as of hypersthene. The analogy is rendered even more complete by the fact, not previously stated, that in the sections of gneissoid gabbro which contain grains of garnet the latter are partially surrounded by radiating tongues like those around the garnet of the gneiss, but often so slender as to make difficult an accurate determination of the mineral composing them. This structure is illustrated in figure 3.

Thus, the black gneiss is closely related to the gabbro in mineralogical composition, showing such differences from it as might result from alteration and metamorphism. At the same time the gneiss has developed on a large scale a peculiar structure which is precisely analogous to a structure shown in the gneissoid gabbro. From these facts it seems justifiable to conclude that at least there is great probability that the black gneiss is a metamorphosed gabbro. The final establishment of the truth or error of this hypothesis will be an important step in unravelling the history of the gneissic complex of the region, for the bowlders of the drift indicate that the black gneiss is a rock of considerable importance. In fact, it may be said of all the rocks described that they are doubtless of much greater extent than might be inferred from the facts

stated, for the dense forest covering the region, the scarcity of trails and the decided similarity in weathered surfaces of the different rocks combine to make it a matter of great difficulty to collect reliable data in regard to their areal relations.

The identification of rocks of the gabbro family in this locality is of interest in being one more piece of evidence indicating a much wider range for this group in the Adirondack region than was formerly supposed to be the case. In the early days of the New York survey the anorthosite was described by Emmons,* under the name hypersthene rock, as limited to Essex County. Colvin† speaks of finding it in another county, but does not state which one. Beecher and Hall‡ in describing the faults of the Mohawk valley speak of the labradorite at Little Falls, but give no description of the rock. Van Hise§ has stated recently that in company with Prof. G. H. Williams, he noted the gabbro in contact with limestone at Bonaparte Lake, Lewis County. Nason‖ mentions the occurrence of "frequent outcrops of the typical labradorite rocks" along the line of the Carthage and Adirondack railroad, in Lewis and St. Lawrence Counties. Finally, the work of Professor Kemp, already referred to, has shown a great expanse of the gabbros in the vicinity of Lake Champlain. In all of these recent papers, with the exception of the last, the reference to the gabbro is merely incidental, and no descriptions of the rock are given. They serve, however, to indicate that this group of rocks is by no means limited to Essex County, but, on the contrary, extends over a large portion of the Adirondack region. Of the various localities mentioned, Little Falls is the nearest to Wilmurt Lake, and is therefore of most interest in this connection. The rock so well exposed in the gorge of the Mohawk river at this place is very coarse grained, usually distinctly gneissoid, and of a greenish-gray color. It is composed chiefly of plagioclase, with some pyroxene, hornblende, mica, and quartz. Its most conspicuous feature is a highly developed cataclastic structure, showing great "augen" of feldspar lying in a mosaic of finely crushed fragments. In composition and structure the rock is precisely like the Canadian anorthosites, in fact the figures of cataclastic structure given by Adams¶ might have been drawn from sections of the Little Falls rock, so close is the resemblance. But more important is the fact that it is practically

* Geology of New York, 2d District, p. 32.
† Adirondack Survey, Second Report, p. 151.
‡ Fifth Annual Report State Geologist, p. 8.
§ Bull. 86, U. S. G. S., p. 399.
‖ Iron-Bearing Rocks of the Adirondacks, Am. Geol., xii, p. 28.
¶ F. D. Adams, Ueber das Norian oder Ober-Laurentian von Canada, Neues Jahrbuch für Mineralogie, etc., B.B. VIII, s. 419.

identical in character with the anorthosites of Essex County and must be regarded as a southward extension of this rock. Now, although Little Falls is nearly thirty miles from the Wilmurt locality, a line connecting it with the Essex County anorthosites would pass less than eight miles to the eastward of Wilmurt. Thus, if, as seems probable, the anorthosite of Little Falls is continuous with that of Essex County, it must approach within a comparatively short distance of the Wilmurt gabbro. The possibility of establishing a connection between the two rocks is thus rendered considerable, so much so in fact that there can be little doubt that the gabbros of Wilmurt Lake and vicinity are an offshoot of the great gabbro core of the Adirondacks.

Hamilton College, Clinton, N. Y., March 7, 1894.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On a Titration method for determining Molecular Mass.*—It has been shown by Nernst that, when foreign substances are dissolved in a given liquid, the solubility of this liquid in another with which it is partly miscible, is diminished in accordance with the same laws as those which regulate the diminution of its vapor pressure when the second liquid is not present. The experimental confirmation of this law has been found difficult owing to the limited number of miscible liquids such as it requires. Küster, however, has succeeded in doing this, using for the purpose a saturated aqueous solution of sodium chloride on the one hand and phenol on the other. If we call L_0 and L the solubilities in water of pure phenol and of phenol containing a foreign substance, g_l and g_s the masses of phenol and of the foreign substance M_l and M_s their molecular masses and V_0 and V the volumes of phenol before and after the addition of the foreign substance we have for the value of the constant k

$$k = (L_0 - L)/L \,.\, g_l/M_l \,.\, M_s/g_s \,.\, V/V_0.$$

This value in Küster's experiments was 1·125.

To apply the results to the determination of molecular mass by titration, Küster uses two separating funnels, of about 100^{cc} capacity, each containing (1) 25^{cc} of a saturated aqueous solution of sodium chloride saturated with phenol at the temperature of the laboratory, and (2) 10^{cc} of phenol saturated with sodium chloride by contact with a strong solution of this salt. Into one of these funnels is now introduced a known mass of the substance whose molecular mass is to be determined. It must be soluble in phenol

and only sparingly soluble in water. Both funnels are then shaken up for two minutes, care being taken to avoid rise in temperature, and they are allowed to settle for half an hour. A plug of cotton wool is placed in the tube of each funnel, and after drawing off 1^{cc} or so, the rest of the filtered aqueous layer is collected in a small flask and well closed. In this aqueous solution the phenol is estimated by titration with bromine; 10^{cc} of the solution being placed in stoppered bottles along with 25^{cc} of bromide-bromate solution and 10^{cc} of 10 per cent hydrochloric acid. After half an hour 10^{cc} of solution of potassium iodide (42 g. pr liter) is added and in 15 minutes the solution is titrated with twentieth normal thiosulphate solution. From the above equation

$$M_o = 1{\cdot}125 g_o 94/10 \,.\, L/(L_o - L).$$

The author obtained for benzene values for the molecular mass ranging from 74·7 to 80·1 (theory requiring 78); for chloroform from 95·9 to 120·0, and for vinyl tribromide from 257·5 to 294; theory requiring 119·5 and 267 respectively.—*Ber. Berl. Chem. Ges.*, xxvii, 324, 328, February, 1894. G. F. B.

2. *On the Use of the Lummer-Brodhun prism in Colorimetry.*—The Lummer-Brodhun prism which has proved of so much service in photometry has been applied by Krüss with equal satisfaction, in colorimetry. This double prism consists of one ordinary total reflecting prism with its hypothenuse-surface plane, and of a second such prism having its hypothenuse-surface spherical, with the exception of a small circular plane surface at the center. The second prism is so adjusted to the first that its plane circle is in the center of the plane hypothenuse side of the other, the two being pressed together so as to leave no air between them. The double prism thus obtained permits light to pass unchanged through its central contact surfaces, while those rays which are incident upon the outer portions of the plane surface are totally reflected. It follows that the transmitted beam appears as a central luminous circle while the totally reflected one is a bright ring surrounding it. If the central image and the annular one are given by different sources of light the point where, on moving away the brighter source, the intensities become equal, can be very exactly determined. In Krüss's colorimeter, the light traversing the prism comes through the one solution, and that reflected by the prism through the other; the arrangement of auxiliary prisms being such that each ray has to pass through an equal thickness of glass and suffer the same number of reflections.—*Zeit. anorg. Chem.* v, 325, November, 1893. G. F. B.

3. *On Electrolysis by Alternating Currents.*—An investigation has been untertaken jointly by Hopkinson, Wilson and Lydall in order to determine first, the energy dissipated by the so-called electrolytic hysteresis, and second, the quantity of an ion per square centimeter of an electrode, required to change the properties of the electrode to that of the ion during alternating current

electrolysis. The experiments were made by passing an alternating current through an ordinary non-inductive resistance and through an electrolyte, the difference of potential at the extremities of these two resistances being measured at different phases of the current. Accompanying the paper are curves of current and potential differences with different frequencies, and also curves showing the dissipation of energy per cycle. As a result it appeared that with platinum electrodes $150^{sq\ cm}$ in area, the ion being hydrogen, the maximum electromotive force due to polarization was reached when one-tenth of a coulomb had passed through the cell. That is to say, when 0·00001 gram of hydrogen had been liberated. It appears therefore that 0·00000007 gram of hydrogen is sufficient to polarize one square centimeter of platinum. If we may assume the density of this hydrogen to be comparable with that of liquids, the thickness of the film of hydrogen necessary is of the same order as this number—$0{\cdot}00000007^{cm}$—a number comparable with the distance between the molecules.—*Proc. Roy. Soc.*, liv, 407; *J. Chem. Soc.*, lxvi, ii, 178, May, 1894. G. F. B.

4. *On the Source of the Hydrogen Peroxide in the Atmosphere.*—From his experiments, Bach has been led to the conclusion that under the action of sunlight carbonic acid undergoes decomposition, yielding percarbonic acid and the elements of formaldehyde according to the equation

$$(H_2CO_3)_3 = (H_2CO_4)_2 + [C + H_2O]$$

The percarbonic acid may subsequently decompose, yielding carbon dioxide and hydrogen peroxide $H_2CO_4 = CO_2 + H_2O_2$. It is to these reactions in his opinion, that the presence of hydrogen peroxide in the atmosphere is due. If a cold saturated and filtered solution of uranium acetate, containing one per cent of freshly distilled diethylaniline, be exposed to the simultaneous action of carbon dioxide and strong sunlight, a violet coloration is developed; although the solution is not thus affected by either of these agents separately. The result, therefore, must be due, the author believes, to the production of formaldehyde and of a compound (percarbonic acid) which will oxidize the leuco-base produced by the action of the formaldehyde upon the diethylaniline.—*Ber. Berl. Chem. Ges.*, xxvii, 340, February, 1894.

G. F. B.

5. *On the Explosive Haloid Compounds of Nitrogen.*—Pure nitrogen trichloride NCl_3 was first prepared by Gattermann in 1888, as an oily liquid, so explosive that sunlight or even the light of burning magnesium caused its detonation. Associated with it, the crude product contained other chlorides of nitrogen. Last year Szuhay produced the compounds NHI_2 and $NAgI_2$, both explosive. The whole subject has now been studied by Seliwanow who shows that the production of the chloride or the iodide of nitrogen by the action of the halogens upon ammonia takes

place in two stages, hypochlorous or hypoiodous acid being first produced. When a dilute instead of a concentrated solution of iodine is employed, no separation of nitrogen iodide occurs and the solution contains both ammonium iodide and hypoiodous acid HIO; this latter substance being readily detected by means of its reaction with potassium iodide. As the strength of the iodine solution is increased, nitrogen iodide begins to be deposited its formation taking place at the expense of the hypoiodous acid. The reactions are: $NH_3+I_2+H_2O=NH_4I+HIO$, and $NH_3+(HIO)_3=NI_3+(H_2O)_3$. The author has shown that a similar explanation holds with reference to nitrogen chloride. The fact that he proves the presence of hypoiodous acid in a solution of ammonia, is interesting in view of the basic properties of this substance as recently established by Victor Meyer.—*Ber. Berl. Chem. Ges.*, xxvii, 1012, April, 1894. G. F. B.

6. *On the Preparation of Phosphorus by the Action of Aluminum upon the Phosphates.*—It has been observed by Rossel and Frank that on heating sodium metaphosphate with aluminum in a current of hydrogen, 28 to 31 per cent of the phosphorus distills over, leaving a residue consisting of alumina, sodium aluminate and aluminum phosphide. The same is true of the phosphates of calcium and magnesium; all of them yielding phosphorus when heated with aluminum. When aluminum is heated in the vapor of phosphorus, aluminum phosphide Al_2P_5 is formed. It is obtained as a gray powder by continuing the heat until the excess of phosphorus is drive off. If silica be added to the mixture of phosphate and aluminum the whole of the phosphorus may be obtained:

$$(Ca(PO_3)_2)_3+Al_{10}+(SiO_2)_3=(CaSiO_3)_3+(Al_2O_3)_5+(P_2)_3.$$

On heating a mixture of calcium metaphosphate and calcium sulphate with aluminum a violent explosion took place which the authors believe to be due to the sulphate; since barium sulphate or calcium sulphate acts with explosive violence when heated with aluminum setting free sulphur.—*Ber. Berl. Chem. Ges.*, xxvii, 52, January, 1894. G. F. B.

7. *On the Production artificially of the Diamond.*—The experiments of Moissan upon the production of the diamond in his electric furnace have been continued. In order to cool the melted iron, it is poured into melted lead. Small globules of the iron rise to the surface and are cooled and solidified before reaching it. When these globules are treated with acids in the usual way the yield of diamonds is somewhat better and they are very limpid, have no black enclosures and some of them show distinct crystallization. In many cases they also show parallel striæ and impressions of cubes similar to those seen on native diamonds. Two specimens thus prepared broke spontaneously after a time. One of them showed distinctly curved faces. Some of these diamonds show smooth and brilliant surfaces while others have a granular surface. In some cases they were found to be trapezohedrons

with twelve faces. In convergent polarized light, some crystals showed no coloration, while others showed feeble colors though less intense than is sometimes seen in natural crystals. Hence the author thinks it probable that carbon like iodine and arsenic, changes at the ordinary pressure and at a sufficiently high temperature from the solid to the gaseous state but under a very high pressure can be liquefied and remain in surfusion taking a crystalline form when it solidifies.—*C. R.*, cxviii, 320; *J. Chem. Soc.*, lxvi, ii, 189, May, 1894. G. F. B.

8. *Electrical Condition of the air in high altitudes.*—The results of experiment by Weber, Elster and Geitel appear to confirm the hypothesis of Peltier that the earth has a negative charge and is also surrounded by an electrostatic field. The equipotential surfaces are approximately parallel to the earth's surfaces, and the positive charge increases with the height as far as previous observations have extended. The amount of vapor in the air, the presence of clouds modifies notably this electrostatic field of the earth. Various measures of the potential of the air at different heights have been made in balloon ascensions. Thus Lecher found at 440, 550 and 660 meters height a potential of 193 voltmeters, while at the surface of the earth 92·2 voltmeters was obtained. Tuma obtained at the height of 410 meters, +40 voltmeters and at a height of 1900 meters +70 voltmeters. R. Börnstein has made, however, two balloon ascensions and obtained results which appear to disprove the theory that the potential increases with the height. The first ascension was made August 18, 1893, near Berlin on a clear day, with still air. The height of 3790 meters was reached, and the electrometer indicated a potential between +88 and −52 voltmeters. The instrument showed marked variations and on the whole, diminution of the potential with the height. At 3000 meters, the potential difference was too small to measure. The results of this ascension however may have been complicated by unusual atmospheric conditions, possibly by the prevalence of an aurora. A second ascension was made from Charlottenburg, September 29. The height of 3943 meters was attained. The potential varied somewhat, attaining a maximum value of +100 voltmeters, and did not reach negative values. It decreased as the balloon rose, at 3300 meters it was not measurable, but became greater as the balloon sank. Feb. 17, 1893, Baschin attained a height of 4000 meters, and also noted a diminution of the potential with increasing height. At a certain height measures were no longer possible. Similar results were obtained in August, 1893, by French observers. Börnstein remarks that five observers, thus independently of each other, have found that the potential decreases with increasing height. The observations seem to point to the conclusion that masses of electricity of positive sign are present in the atmosphere. In the discussion of Börnstein's paper Professor Bezold pointed out that our knowledge of atmospheric electricity can be gained better from balloon ascensions than from observations

from high points on the earth's surface, for at such high points it is impossible to obtain conditions of uniformity. If we had numerous observations at different heights taken in balloon ascensions, we could construct curves which would show at a glance the electrical conditions of the atmosphere.—*Proc. Physical Society Berlin*, March 16, 1894. *Ann. der Physik und Chemie*, No. 6, 1894, pp. 85–50. J. T.

II. Geology and Mineralogy.

1. *The United States Geological Survey.*—The recent resignation of Major J. W. Powell, and the appointment of Charles D. Walcott to be his successor as Director of the U. S. Geological Survey, mark the completion of the first fifteen years of this important Government Bureau.

Congress did not organize this survey, but in a couple of clauses of the Appropriation bill of March 3, 1879, established the office of "Director of the Geological Survey," made the necessary appropriations for his salary and for the expenses of the survey, and placed upon the Director the duty of "directing the Geological Survey, the classification of the public lands, the examination of the geological structure, mineral resources and products of the national domain."

Clarence King was the first Director and performed the important function of organizing the Survey and setting it in motion. In 1881 Mr. King resigned and Major J. W. Powell took up the task of directing the survey, and it is largely due to the energetic directing of the survey by these two officers that such grand results have been accomplished in so short time. In fact the criticism of the administration of the survey has been directed chiefly against the too energetic extension of its investigations into fields thought, by the critics, to be outside the legitimate province of the survey.

The broadening of the area of the survey from the "national domain," to which it was at first restricted, to include the whole territory of the United States has resulted in opening the grander problems of the geological structure and development of a continent to scientific study, and has already been found entirely practicable—aiding and not interfering with local state surveys.

The great attention paid to topographical surveys has been criticised both by those calling for more thorough work than has been done, and by those jealous of enroachments upon the more specific province of a geological survey—i. e. the elaboration of the geology of the country. Topographic maps are undoubtedly necessary to the minute study of the geology of a region, but their construction should not be made the chief work of a geological survey.

The segregation of lands in the arid regions for irrigation reservoirs, however important for the regions concerned, is not the legitimate function of a geological survey, and the transfer of this

work either to a separate organization, or to the individual States to be benefited thereby, would relieve the survey from both criticism and expense.

The paleontological work of the Survey has been done on a scale which has excited the admiration of the scientific world. When we consider the marvelous revelations which American paleontology has made in the past few years any undue expenditure in this direction may be charged to the lavishness of our rocks in paleontological wonders rather than to any wastefulness on the part of the survey. Paleontology is the basis of all interpretation and classification of the geology of stratified rocks, and we hope that the selection of one of our ablest paleontologists to be Director will result in the application of the thorough methods of research, used by Mr. Walcott in his interpretation of the Cambrian, to all the departments of the United States Geological Survey.

H. S. W.

2. *An Introduction to the Study of the Brachiopoda*, intended as a Handbook for the Use of Students. By JAMES HALL, assisted by JOHN M. CLARKE. (Report of State Geologist of N. Y. for 1891.) Pp. 135–300, plates 1–22, 1894.

It is seldom that the authors of special monographs devote their time and knowledge to the preparation of a general elementary work which will enable the student to gain a comprehensive view of a given subject. The Brachiopods are an especially favored class of animals. Davidson, in 1851, published his well-known and able "Introduction," which showed what might be expected when the recent and fossil forms had been more thoroughly studied. Œhlert, later, in 1887, prepared the section relating to Brachiopods for Fischer's "Manual de Conchyliologie." It has been considered the best modern treatise on the class, and is in every way an admirable resumé. Zittel has also given an excellent review of the group in his "Handbuch der Palæontologie."

The authors of the present work are especially fitted for the task through their long and intimate investigation of the Genera of Palæozoic Brachiopoda (vol. viii, Palæontology of New York), and it is safe to assume that this handbook embodies a more critical knowledge of the class than it has hitherto received in similar elementary works.

The introductory portion treats of the leading characters of the Brachiopoda, together with their geographic and bathymetric distribution. The features of the shell are then discussed, with the variations in form, ornamentation, and the special characters of the cardinal area and delthyrium. The internal configuration of the valves receives considerable attention, and includes features of the articulating apophyses, muscular scars, pallial sinus, genital markings, and structure of the test. The portion relating to the animal itself gives a summary of the structure of the mantle and pedicle, the muscular, alimentary, neural, and reproductive systems, and the numerous modifications of the brachia in various

groups of genera. The last of the general introductory matter is on the embryology and especially the early and post-embryonic stages in the development of the shell.

These observations are followed by succinct descriptions of the genera, with mention of their geological range and the type species. The genera are well illustrated in the twenty-two lithographic plates accompanying this work which were drawn in the most perfect manner by Philip Ast, the well-known artist of the Palæontology of New York.

The present volume includes the inarticulates with the orthoid, strophomenoid, and productoid genera of the articulates. The authors propose to complete the work with plates and descriptions of the spire- and loop-bearing forms, together with a general chapter on the classification of the Brachiopoda. C. E. B.

3. *Bibliotheque Gèologique de la Russie*, vol. viii, 1892, par S. NIKITIN, pp. 1–215, St. Petersbourg and Paris, 1893.

The eighth volume of this valuable digest of Russian geological literature contains titles and brief synopses of contents, in both Russian and French, of the literature of 1892. Its value is increased by the addition of full indices, arranged according to subjects, geographic, biologic and authors' names.

4. *Illustrations of the Fauna of the St. John Group*, No. VIII; by G. F. MATTHEW. (Trans. Roy. Soc. Canada, Section iv, 1893.) pp. 85–129, Plates xvi, xvii, 1894.

In the closing number of this important monograph, which has been issued serially, is added a "list of the Fossils of the Cambrian and Ordovician rocks in and near St. John, being those of the Basal or Etcheminian series and of the St. John Group," in which are listed 220 species and varieties.

The following thicknesses are given of the rocks of the St. John Basin, viz:

Basal series (Etcheminian) at Hanford Brook, St. Martin's,	1,200 ft.
Division 1 (Acadian) at the Alms House, Simonds,	650 "
Division 2 (Johannian) at King's Square, Carleton,	1,000 "
Division 3 (Bretonian) at Straight Shore, Portland,	700 "
	3,550 ft.

At the close of the paper the author remarks on the use of the name St. John group as follows:

"Since the range of the terrain is now known, the name St. John group cannot be used as synonymous with Cambrian; nor is it of value as that of a group with a specialized fauna of local import only. It is rather to be regarded as presenting a phase of the Cambrian and Ordovician faunas of regional value, and especially as showing a succession of American faunas of those times, having close relations with the co-temporaneous faunas of Europe. Its claim to general use has been abrogated by the discovery of its faunas, and it now stands on much the same footing as the Quebec group of Sir Wm. Logan. These names must give place to the older ones, Cambrian and Lower Silurian

(=Ordovician), since both the St. John and the Quebec groups include strata of two great geological systems." (pp. 120–121.)

5. *Fossil resin.*—The following chemical analyses of specimens of a fossil resin of black color from two horizons in the Tertiary formation in Alabama, viz: the base and the summit of the Eocene, imbedded in impure limestone, are reported by EUGENE A. SMITH, the State Geologist, in a letter to the editors.

The analyses were made by Dr. Wm. B. Phillips.

No. 1. Marengo Co., Ala. Base of Eocene.
No. 2. Barbour Co., " " "
No. 3. Choctaw Co., " Top "

PROXIMATE ANALYSES.

	I.	II.	III.
Volatile matters	57·65	62·85	62·90
Fixed carbon	41·00	36·20	34·50
Ash	·15	·85	2·30
Moisture	1·20	·10	·30
	100·00	100·00	100·00

ULTIMATE ANALYSES.

	I.	II.	III.
Carbon	63·88	59·86	54·47
Hydrogen	9·07	7·90	7·72
Oxygen by difference	20·21	26·17	29·71
Nitrogen	0·37	0·63	0·22
Sulphur	5·12	4·49	5·28
Ash	·15	·85	2·30
Moisture	1·20	·10	·30
	100·00	100·00	100·00

6. *Papers and Notes on the Glacial Geology of Great Britain and Ireland;* by the late HENRY CARVILL LEWIS, M.A., F.G.S., Professor of Mineralogy in the Academy of Natural Sciences, Philadelphia, and Professor of Geology in Haverford College, U. S. A. Edited from his Unpublished MSS. with an Introduction by Henry W. Crosskey, LL.D., F.G.S. London: Longmans, Green & Co. 1894. 8vo, pp. lxxxi, 469.—The sudden death of Professor Lewis in July, 1888, just as he was beginning to revise his field work on glacial geology in Great Britain and Ireland, led many to fear that the world had lost the greater part of the work already done by him, for there are few observers whose field notes can be safely published without the author's own revision; but those who knew the habits of Professor Lewis expected that his notes upon this subject would prove of inestimable value. They are not disappointed. The present volume of 550 elegantly printed 8vo pages, is really one of the most important contributions to glacial geology which has yet been made. The late Rev. Henry W. Crosskey has furnished an introduction

of great value, and Prof. Percy F. Kendall has added an appendix ably supplementing the observations and inferences of Professor Lewis. But the main work is still that of Lewis in which we are permitted to travel with him over almost the whole of Great Britain and Ireland and see what he saw of the glacial facts upon which his theories were based. Professor Lewis' eye was both sensitive and highly trained, and he records fully the separate facts as they are. In this respect the volume very much resembles the separate volumes of the Second Geological Survey of Pennsylvania, and reflects the good judgment of Professor Lesley who furnished the pattern for the reports of the Pennsylvania geologists in whose company Professor Lewis began his scientific work. The volume contains ten elaborate maps and one hundred or more illustrations. The author's minute acquaintance with the glacial phenomena of Pennsylvania enabled him through comparison to see the meaning of the English facts as no local observers had been able to do. He was led to believe in the continuity of the glacial period and to reject the theory of an extensive submergence of the British Isles in connection with it. His greatest triumph is what may be called a *reasonably complete demonstration* that the high-level shell-beds at Macclesfield and Moel Tryfaen were not deposited during a period of submergence, but consisted of material which had been incorporated into the till, pushed up by the glacier from the Irish Sea. The work of Professor Lewis marks an epoch in English glacial geology, and Alfred Russel Wallace has recently given his adhesion to the most important of the revolutionary views so ably defended in this volume. Great credit is due to Mrs. Lewis for the expense and pains which she has bestowed in making the unrivalled work of her husband available to the scientific public. G. F. W.

7. *Brief notes on some recently described minerals.*—Under the name of *Knopite*, HOLMQUIST has described an apparently isometric mineral from Alnö which is very near to perofskite but differs in containing cerium as shown in the analysis.

SiO	TiO_2	ZrO_2	FeO	MnO	MgO	Ce_2O_3	CaO	K_2O	Na_2O	H_2O	
1·29	58·74	·91	3·23	·31	·19	5·80	26·84	·75	·29	1·00	= 99·35

Two types of the mineral are given and the optical anomalies are fully discussed.—*G. För. Förh.* xvi, *p.* 73, 1894.

Recently L. J. IGELSTRÖM has described a number of supposed new antimony and arsenic minerals from the Sjögrube Örebro, Sweden. Thus *Lampeostibian*, a ferrous manganous antimonate apparently tetragonal, *Elfstorpite* a manganous arseniate, perhaps orthorhombic, *Shloroarsenian* a possible manganous arseniate, *Rhodoarsenian* occurring in small pink spheroids, for which the following composition is given after deducting some admixed calcite.

As_2O_5	MnO	CaO	MgO	H_2O by diff.
12·17	49·28	21·53	5·37	11·65

This is interpreted to stand for $10RO.As_2O_5 + 10R(OH)_2$ where R=MnCa&Mg. Hardness 4, vitreous luster, pale pink streak. Easily soluble in HCl. *Basilite* a foliated dark metallic bluish looking mineral occurring with hausmannite. In thin foliæ translucent with blood-red color. An analysis on impure material gave

Sb_2O_5	Mn_2O_3	Fe_2O_3	H_2O
13·09	70·01	1·91	15·00

Sjögruvite occurs in thin lamellæ in veins and druses with jacobsite. Translucent blood-red color. Streak yellow. The analysis gave:

As_2O_5	MnO	Fe_2O_3	CaO	PbO	H_2O	
49·46	27·26	11·29	3·61	1·74	6·81	= 100·17

This brings it very near Arseniöpleite previously described by the same author. All of these minerals are however so imperfectly investigated that it is impossible to say whether they will stand as definite new species or not. Some of them have been determined as such only by qualitative analyses carried out upon material of doubtful purity. All crystallographic and nearly all physical examinations are wanting. Such work in mineralogy is to be greatly deplored as tending to promote confusion and disorder.—*Zeit. f. Kryst.*, p. 467, vol. xxii, 1894.

Rittingeaite has been shown by MIERS to be identical with *Xanthokonite*. The former name thus becomes only a synonym. Also that the mineral is really monoclinic, ang. $\beta = 88° 47'$ simulating hexagonal symmetry. In conjunction with this, the analytical work by PRIOR shows that it is a silver sulpharsenite and not a sulpharsenate. Thus it has the same composition as proustite, the molecule Ag_3AsS_3 being dimorphous (*Ibid.* 433).

Frankeite is a new mineral from the mines in the Dept. of Potosi, Bolivia, described by STELZNER. An analysis by WINKLER gave

Pb	Sn	Sb	S	Fe	Zn	Gang	
50·57	12·34	10·51	21·04	2·48	1·22	0·71	=98·87;

the iron and zinc being deducted as pyrite and sphalerite, the remainder gives the formula $Pb_5Sn_2Sb_2S_{12}$. Traces of germanium were also found. Occurs in radiating fibrous or foliated masses. Cleavage in one direction good. H.=$2\frac{3}{4}$. Sp. Gr.=5·55. Luster metallic, opaque, color blackish gray to black. Under the name of "Ilicteria" is known as an ore.—(*Jahb. f. Min.* 1893, vol. ii, p. 114).

L. V. P.

8. *Manuel de Mineralogie;* par A. DES CLOISEAUX, tome 2d deux. fasc. Paris, 1893. (Dunod.)—The first volume of this work appeared in 1862, the last part of the second volume in 1874. Of the plan and scope of the work it is unnecessary to say anything here, it is familiar to every mineralogist of every nationality, and it is a matter of congratulation that the veteran mineralogist, whose services to science have been so great, has

been able to add this further contribution to his important work. The present part includes the phosphates, arsenates, etc. The author proposes to issue a third volume describing the sulphates and allied species. L. V. P.

III. Astronomy.

1. *Total Eclipses of the Sun;* by Mabel Loomis Todd. Boston, Roberts Brothers. 12mo, 1894, pp. 244.—This is a very pleasantly written volume, designed not for astronomers but for those without technical knowledge who are curious as to the strangely impressive phenomena of total eclipses. It is profusely illustrated, and professional astronomers will, we believe, find the little volume not only interesting but useful, as it has an extensive index and abundant references to original sources.

2. *Publications of the Lick Observatory of the University of California.* Vol. II, Sacramento, 1894. 4°, pp. 255.—This volume contains Mr. Burnham's observations at Mount Hamilton upon double stars made with the 36 inch and the 12 inch refractors of the Lick Observatory between August, 1888, and June, 1892. The six catalogues, Nos. 14–19, of new double stars discovered by Mr. Burnham at Mount Hamilton, and originally contributed to the *Astronomische Nachrichten*, are included in this volume.

3. Prof. M. Updegraff, who has had charge of the Laws Observatory of the University of the State of Missouri at Columbia since July, 1890, has communicated to the Academy of Sciences of St. Louis a description of the building and principal instruments together with the determination of the latitude, longitude, and altitude above sea level of the Observatory. These are:

Mean N. latitude,	$38° 56' 51''{\cdot}70 \pm 0''{\cdot}08$
W. longitude,	$6^h 9^m 18^s{\cdot}334$
Height above sea level,	737·41 feet.

The equatorial telescope is a refractor of 7·45 inches clear aperture, made in Munich, and used by Prof. Winlock at Shelbyville and at Cloverden. It has been provided with a spectroscope by Fauth. The transit instrument has a clear aperture of 2·10 inches.

IV. Botany.

1. *Guide to Sowerby's Models of British Fungi in the Department of Botany, British Museum*, 1893. 8°, pp. 82. Figs. 93.—This attractive pamphlet which is offered to the visitors of the British Museum for the moderate sum of fourpence is intended as a guide to the collection of models of edible and poisonous fungi made by James Sowerby during the publication of his classic work, English Fungi, 1797–1809. The collection was exhibited to the public during Sowerby's life in his own house and after his death it became the property of the British Museum. It con-

sisted of more than two hundred models most of which were made of unbaked pipe-clay and being very fragile they had become somewhat injured with time but they have been skilfully restored by Mr. Worthington G. Smith, so that the collection is one of the finest in existence. Probably the only other collections to be compared with it are the wax models made by Pinson after Bulliard's plates in the Museum of the Jardin des Plantes in Paris and the models made by Barla in the Museum at Nice of which there is also a duplicate series in the Ecole de Pharmacie in Paris. The figures which illustrate the Hymenomycetes are from Stevenson's British Fungi and the remainder were prepared by Mr. Smith, who also wrote the text which includes numerous remarks on edible and poisonous properties of the different species, the result of Mr. Smith's large experience. W. G. F.

2. *A Monograph of Lichens found in Britain: being a Descriptive Catalogue of the Species in the Herbarium of the British Museum;* by the Rev. James M. Crombie. Part I. 8°. Pp. 518. Figs. 74. London, 1894.

This excellent monograph, printed by order of the Trustees of the British Museum, although treating specially of British Lichens will prove to be of great value to American lichenologists on account of the illustrations of the fruit of different genera, the clear descriptions and well arranged synonymy. In fact we know of no treatise covering the same ground in which the student of lichens will find so much information as to the generic and specific distinctions presented in a compact and comparatively inexpensive form. The present volume includes the greater part of the gymnocarpic forms, the *Lecideæ*, *Graphidei* and angiocarpic forms being reserved for another volume. The order of genera is essentially that of Nylander's Synopsis, but *Myriangium*, a genus which in our opinion should not be included in lichens in any sense, is placed after the angiocarpous forms. Perhaps the most valuable part of the volume is that relating to *Ephebacei* and *Collemacei*, very perplexing families, the descriptions of whose species have hitherto been scattered in different papers and journals not infrequently inaccessible to the student. We regret, however, that in the description of the gonidia, or gonimia as they are called in these families by lichenologists, the author has retained the cumbersome terminology of lichenological treatises instead of referring them to the alga—forms which, to say the least, they resemble. As an illustration we may take *Ephebei* whose gonidia are described as "gonimia tunicated in nodulose syngonimia." Since they are undistinguishable from the alga-genus *Stigonema*, a genus which must be familiar to lichenologists as well as others, it seems to us that it would be better to describe the gonidia in this case by the word Stigonematoid. The convenience and accuracy of such an adjective seems to us to be quite independent of the question whether a writer accepts or denies the validity of the alga-fungal theory of the nature of lichens. So far as the general descriptions are concerned they are

excellent, spore characters, chemical reactions, habitats and localities being given sufficient but not too great prominence, so that the whole appears well proportioned. In several genera, as *Usnea*, forms generally classed in this country as varieties and regarded as such in Nylander's Synopsis are raised to the rank of species. It is to be hoped that the author will be able soon to publish the second volume for, at present, we have no treatise in which the species of *Verrucaria* and their allies are adequately described, not to mention the scattered condition of the literature relating to *Lecideei* and *Graphidei*. W. G. F.

V. Miscellaneous Scientific Intelligence.

1. *The Condition of Kilauea March 20th*, 1892; by F. S. Dodge.—A paper by Mr. Dodge in vol. xlv of this Journal contains an account of the crater of Kilauea at the time of his survey in August, 1892. A recent letter, dated the 26th of March last, states that since that on the 20th, he had found great changes since 1892.

The deep pit of Halemaumau or pit at the southwest end of the crater of Kilauea had become completely filled up by overflows from its lake; and the lake has thereby raised until now its level is but 75 feet below the Volcano House datum; and it is still rising. [The Volcano House is on the northeast border of the crater of Kilauea; and in 1887, the highest part of the margin of Halemaumau was 320 to 330 feet below the Volcano House datum.] The lake has increased in size by the addition of a circular portion—on the S. W. or Kau side—the total area being now about 15 acres, and the newer portion is the scene of the greatest activity. Seven overflows were counted at one time last Tuesday evening. The largest was fully 50 feet in width at the outlet, and extended to the foot of Kau bluff near Uwekahuna, the west side of Kilauea. The rise in the lake has been 447 feet since Aug. 1892, and now a flat cone surrounds the lake, so that instead of a pit with a lake in its bottom area, there is a low broad cone with the lake on its summit, and it is this summit which is only 75 feet below the datum point at the Volcano House.

2. *On the Leicester Earthquake of August* 4, 1893; by Charles Davison. (Read before the Royal Society, London), February 28, 1894. (Abstract.)

On August 4, 1893, at 6.41 P. M., an earthquake of intensity nearly equal to 6 (according to the Rossi-Forel scale) was felt over the whole of Leicestershire and Rutland and in parts of all the adjoining counties. The disturbed area was 58 miles long, 46 miles broad, and contained an area of about 2066 square miles. The direction of the longer axis (about W. 40° N. and E. 40° S.) and the relative position of the isoseismal lines show that the originating fault, if the earthquake were due to fault-slipping, must run in about the direction indicated, passing between Wood-

house Eaves and Markfield, and heading towards the northeast. The anticlinal fault of Charnwood Forest, so far as known, satisfies these conditions, and it is highly probable that the earthquake was caused by a slip of this fault.

The beginning of the sound preceded that of the shock in all parts of the disturbed area; the end of the sound followed that of the shock in the central district and in the neighborhood of the minor axis, but preceded it near the end of the major axis. Thus the sound apparently outraced the shock in the direction of the major axis, but not in that of the minor axis. These time-relations of the sound and shock can be readily explained if the area over which the fault-slip took place were several miles in length, for the sound in all probability is due to small and rapid vibrations proceeding chiefly from the margins of that area.

The intensity was greatest at and near Woodhouse Eaves, and it is probable that the fault-slip began in the neighborhood of this place, gradually diminishing in amount in either direction, rather rapidly towards the northwest, and much more slowly towards the southeast; the rate at which the slipping advanced being greater than the velocity of the earth-wave. The total length of the fault-slip may have been as much as 12 miles or even more and there can be little doubt that it was continued for some distance under the Triassic rocks on which Leicester is built.

3. *Congrès Geologique International.* Compte Rendu de la 5me Session, Washington, 1891, i–ix, pp. 1–529, figs. 1–39, pls. i–xxi, Washington, 1893.

This Report of the fifth session of the International Congress of Geologists, held in Washington in 1891, prepared by the general Secretary S. F. Emmons, like most of its predecessors, contains much valuable matter in addition to the Procès-verbeaux of the proceedings of the Congress itself.

Part first gives a brief account of the history of the Congress; part second contains the Procès-verbeaux; part third contains reports of special discussions; A communications, and B discussions on the correlation of rocks; C discussion upon the classification of the Pleistocene deposits; D discussion of the color-scheme for geological maps, and E a brief compte-rendu of the geological excursions. Part 4, more than one-half the volume, contains illustrated explanations of the three main excursions; A, Geology of Washington and vicinity, prepared by W. J. McGee, with the collaboration of G. H. Williams, Willis and Darton; B, Geological Guide Book of the Rocky Mountain Excursion, edited by S. F. Emmons, parts of it being written by Gilbert, G. H. Williams, I. C. White, Orton, Emmons, Grant, Eldridge, Hague, Iddings, Weed, Peale, Cross, Walcott, and McGee, and interesting notes are added by the visiting geologists, T. McK. Hughes, Fritz Frech and H. M. Cadell. The thanks of all geologists are due to Mr. Emmons for so successfully editing this valuable report, and to the Government, through the U. S. Geological Survey, for its excellent publication. H. S. W.

4. *An international Congress of applied Chemistry* is to be held at Brussels, Aug. 6th to 11th. Mon. F. Sachs (rue d'Allemagne, 68), and H. Van Laer (rue de Holland, 15), Brusselles, are the general secretaries of the committee of organization.

The Lower Silurian Lamellabranchiata of Minnesota: by E. O. ULRICH, pp. 475–628, pls. xxxv–xlii. (From vol. iii of the Final Report of the Geological and Natural History Survey of Minnesota.) June 16, 1894.

Études industrielle des Gites Métallifères; par GEORGE MOREAU. pp. 439, fig. 1–39. (Baudry et Cie.) Paris, 1894.

On the hereditary transmission of acquired characters: by WM. H. BREWER. (Agricultural Science. Vol. vi, and Vol. vii; a series of nine papers closing with Vol. vii. pp. 433–438.) 1893.

The volcanoes of the Kula basin in Lydia; by HENRY STEPHENS WASHINGTON. pp. 1–67. Pls. i–iv. New York, 1894.

Iron ores of North Carolina, a preliminary Report; by HENRY B. C. NITZE, Assistant Geologist. (Bulletin No. 1, North Carolina Geological Survey, J. A. Holmes, State Geologist.) pp. 1–233, figs. 1–58, pls. I–XX, one map. Raleigh, 1893.

The Relation of Biology to Geological Investigations; by CHAS. A. WHITE. From the Report of the U. S. National Museum for 1892, pp. 245–368 (with plate xiv). Washington, 1894.

Geomorphology of the Southern Appalachians; by C. WILLARD HAYES and MARIUS R. CAMPBELL, from the National Geographic Magazine. Vol. vi, pp. 63–126. Pls. 4–6. Washington, 1894.

Iowa Geological Survey, Vol. II, *Coal Deposits of Iowa;* by CHARLES ROLLIN KEYES. pp. 536. Pls. I–XVIII. Des Moines, 1894.

United States Geological Survey, Bulletins.—The following Bulletins have been recently published:

97. The Mesozoic Echinodermata of the United States, by W. B. Clark. 1893. 8°. 207 pp. 50 pl.

98. Flora of the Outlying Carboniferous Basins of Southwestern Missouri, by David White. 1893. 8°. 139 pp. 5 pl.

99. Record of North American Geology for 1891, by Nelson Horatio Darton. 1892. 8°. 73 pp.

100. Bibliography and Index of the Publications of the U. S. Geological Survey, 1879–1892, by Philip Creveling Warman. 1893. 8°. 495 pp.

101. Insect Fauna of the Rhode Island Coal Field, by Samuel Hubbard Scudder. 1893. 8°. 27 pp. 2 pl.

104. Glaciation of the Yellowstone Valley north of the Park, by W. H. Weed. 1893. 8°. 41 pp. 4 pl.

105. The Laramie and the overlying Livingston Formation in Montana, by Walter Harvey Wood, with Report on Flora, by Frank Hall Knowlton. 1893. 8°. 66 pp. 6 pl.

106. The Colorado Formation and its Invertebrate Fauna, by T. W. Stanton. 1893. 8vo. 288 pp. 45 pl.

107. The Trap Dikes of Lake Champlain Valley and the Eastern Adirondacks, by J. F. Kemp. 1893. 8°. 62 pp. 4 pl.

108. A Geological Reconnoissance in Central Washington, by Israel Cook Russell. 1893. 8°. 108 pp. 12 pl.

12th Annual Report of the United States Geological Survey. 1890–91. By J. W. POWELL, director, Part I Geology, xiii, 675 pp. 53 pl. Part II Irrigation, xviii, 576 pp. 146 pl. Washington, 1891. (Vol. I contains—The Origin and Nature of Soils, by N. S. Shaler; pp. 213–346; The Lafayette formation, by W. J. McGee; pp. 347–524; The North American Continent during Cambrian time, by C. D. Walcott; pp. 523–568; The Eruptive rocks of Electric Peak and Sepulchre Mountain, Yellowstone National Park; by J. P. Iddings; pp. 569–664.)

The following extracts from the 13th Annual Report of the Director of the U. S. Geological Survey have appeared:

The Mechanics of Appalachian structure, by Bailey Willis.

The Rensselaer Grit Plateau in New York, by T. Nelson Dale.

Second Expedition to Mount Saint Elias, by Israel Cook Russell.

The Average Elevation of the United States, by Henry Gannett.

The American Tertiary Aphidæ, by S. H. Scudder.

APPENDIX.

ART. X.—*Footprints of Vertebrates in the Coal Measures of Kansas;* by O. C. MARSH. (With Plates II and III.)

THE Museum of Yale University contains a small collection of footprints of much interest, which were found in 1873, in the Middle Coal Measures, near Osage, in southeastern Kansas. This collection is part of a larger series of specimens obtained at the locality by the late Prof. B. F. Mudge, who published a short notice of the discovery, which was subsequently copied in this Journal (vol. vi, p. 228, 1873). The writer examined this entire collection at Manhattan, Kansas, in the autumn of 1873, and secured it for the Yale Museum. The more important specimens were then sent to New Haven, and tracings and notes were taken of the others, which were left to be forwarded later. A careful re-examination of these footprints has been recently made by the writer, and the main results are given in the present article.

The impressions are well preserved in a calcareous shale, which separates readily into thin slabs, each representing a surface of the beach at the time the footprints were made upon it. A few shells in the shale are sufficient to prove that the formation is marine. Trails of annelids, and perhaps of other invertebrates, are seen on some of the surfaces. The footprints of vertebrate animals, however, are of paramount importance, and the large number and variety of these here recorded on a single surface, if they could be rightly interpreted, would form an interesting chapter of land vertebrate life in the Carboniferous, about which so little is at present known.

On Plate II, accompanying the present article, five distinct series of footprints are shown, each one-twelfth natural size. All were found on essentially the same surface, and at one locality. The five different animals they represent were thus contemporaries, and indicate a wealth of air-breathing, land vertebrate life at this period, hitherto unsuspected.

With these impressions were still others, made either by animals nearly allied or by the same animals under different circumstances. These need not be further noticed in this connection, but they serve to emphasize the diversity of life at this point. The typical series are briefly described below.

Nanopus caudatus, gen. et sp. nov.

The first series represented on Plate II, figure 1, indicates the smallest animal that here left a distinct series of footsteps, and the only one in which an imprint made by the tail was preserved. This small quadruped had evidently but three functional toes on the fore feet and four on those behind. The fore feet were considerably smaller than the hind feet. The impressions made by the latter are nearly all separate from the anterior footprints, although at times slightly overlapping them. One fore and one hind footprint of this series are represented, natural size, on Plate III, figure 1.

The nature of the animal indicated by these impressions can at present be a matter of conjecture only, but the probabilities are in favor of its reference to the Amphibians rather than to the true *Reptilia*. As it is evidently distinct from anything hitherto described, the above name is proposed for it.

Limnopus vagus, gen. et sp. nov.

In figure 2, Plate II, a second series of footprints is represented, somewhat larger than those above described, and evidently made by a very different animal. A fore and hind footprint of this series are shown, natural size, in figure 2, Plate III. The front feet had four functional toes, while those behind had five, all well developed. The impressions of the hind feet, as a rule, overlap those of the corresponding fore feet. No indications of a tail can be detected. In length of stride, and in the distance between the footsteps of the right and left sides, the present series is proportionately about the same as those above described, although the animals differed much in size. They were probably both Amphibians, and may have been nearly allied.

Dromopus agilis, gen. et sp. nov.

The third series of footprints shown on Plate II, figure 3, is of special interest, and indicates an animal very distinct from the two already described. On Plate III, figure 3, an outline impression is given, natural size, of one double footmark of this series, made by the fore and hind feet of the left side. This diagram represents the impression of the phalanges sufficiently in detail to indicate their number and general form. A striking feature in the fore and hind feet of this animal was

the long, slender digits, terminated by sharp claws. Another point of interest, as recorded in the footprints, is that the animal in walking swung the hind feet outward, and so near the ground that the ends of the longer toes sometimes made trails in the mud, marking accurately the sweep of the foot. This would seem to indicate a comparatively short hind leg, rather than the long, slender one which the footmarks themselves naturally suggest.

The animal that made these interesting footprints was probably a Lacertilian rather than an Amphibian, but there is also a possibility that it was a primitive Dinosaur.

Allopus littoralis, gen. et sp. nov.

Besides the footprints above described, which pertain to animals of comparatively small size, there are several other series in this collection made by very large animals, which were probably all Labyrinthodonts. These tracks were made on the same beach, and at about the same time as the small footprints, but not all under the same circumstances. The largest animal thus represented appears to have walked on one part of the beach that was quite firm, leaving very shallow footprints, and again to have traversed another part, quite near the first, but slightly covered with water, or at all events so soft that deep impressions were made by the feet, while the toes of the hind feet also left deep trails as they swung outward at each step. On Plate II, figures 4 and 4a, these two kinds of footprints are represented. They show the stride of the animal, and, as put together, also denote the width between the footprints of the two sides, so that the series can be compared with the others on the same plate.

These tracks show that the animal had five toes in the fore feet and four behind. The hind feet show a distinct impression of a sole. There is no imprint of a tail, even where the mud appears to have been deep.

Baropus lentus, gen. et sp. nov.

The most abundant of the large footprints are represented by several series, which are remarkably uniform in stride and in width between the right and left rows. One of these series is represented on Plate II, figure 5, and this is typical of the others. The animal that made these footprints evidently had four functional toes in front and the same number behind. On the inner side of each foot, however, there was a projection, which, in the hind feet, was quite prominent and characteristic, but can hardly be interpreted as the imprint of the first digit. Nearly all these footprints show a distinct impression of a sole. This is usually faint in the tracks of the fore feet, but strongly marked in those behind.

It is hardly necessary at this time to attempt a detailed comparison of the footprints above described with those already on record, but the writer hopes to do this later. The present specimens all have well-marked characters, and, being from a single horizon and locality, have a value of their own as throwing light on the land vertebrate life, during the deposition of the true Coal Measures. If, in themselves, they add but little to what is already known, they at least offer encouragement to investigators in an interesting field not yet systematically explored. The publications of Logan, Lyell, King, Lea, Dawson, and others, have already made known discoveries of importance in this country, and others have been recorded in the Old World.

So far as at present known, land vertebrate life began in the Carboniferous age, no footprints or other remains of this kind having been detected below the Subcarboniferous. That such remains will eventually be found in the Devonian, there can be no reasonable doubt, and perhaps even in the Silurian, if the land surfaces then existing can be explored.

Yale University Museum, New Haven, Conn., June 12, 1894.

EXPLANATION OF PLATES.

PLATE II.

FIGURE 1.—Series of footprints of *Nanopus caudatus*, Marsh; showing, also, impression made by the tail.

FIGURE 2.—Series of footprints of *Limnopus vagus*, Marsh.

FIGURE 3.—Series of footprints of *Dromopus agilis*, Marsh; showing trails made by the toes.

FIGURE 4.—Two pairs of footprints of *Allopus littoralis*, Marsh; right side.

FIGURE 4a.—Footprints of same; showing trails made by the toes; left side.

FIGURE 5.—Series of footprints of *Baropus lentus*, Marsh.

All the figures are one-twelfth natural size.

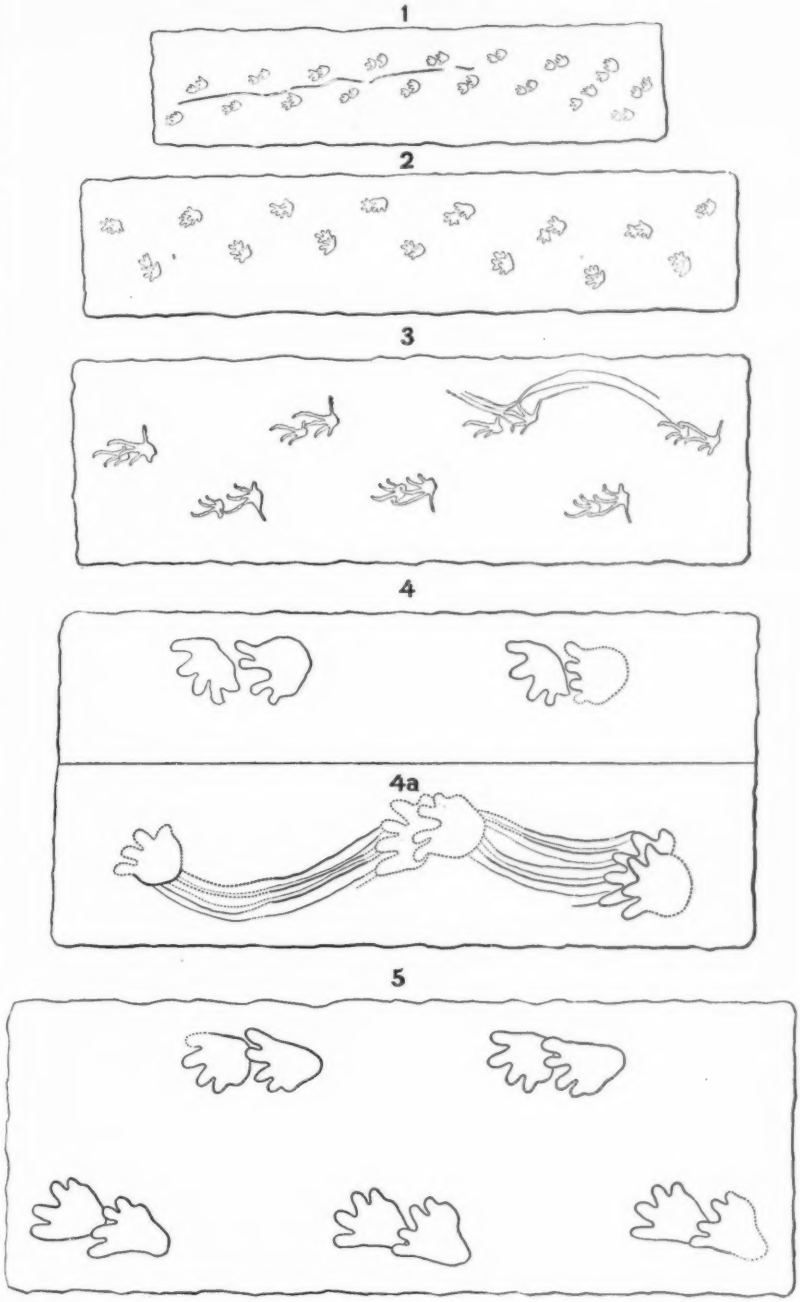
PLATE III.

FIGURE 1.—Outline of left fore and hind footprints of *Nanopus caudatus*.

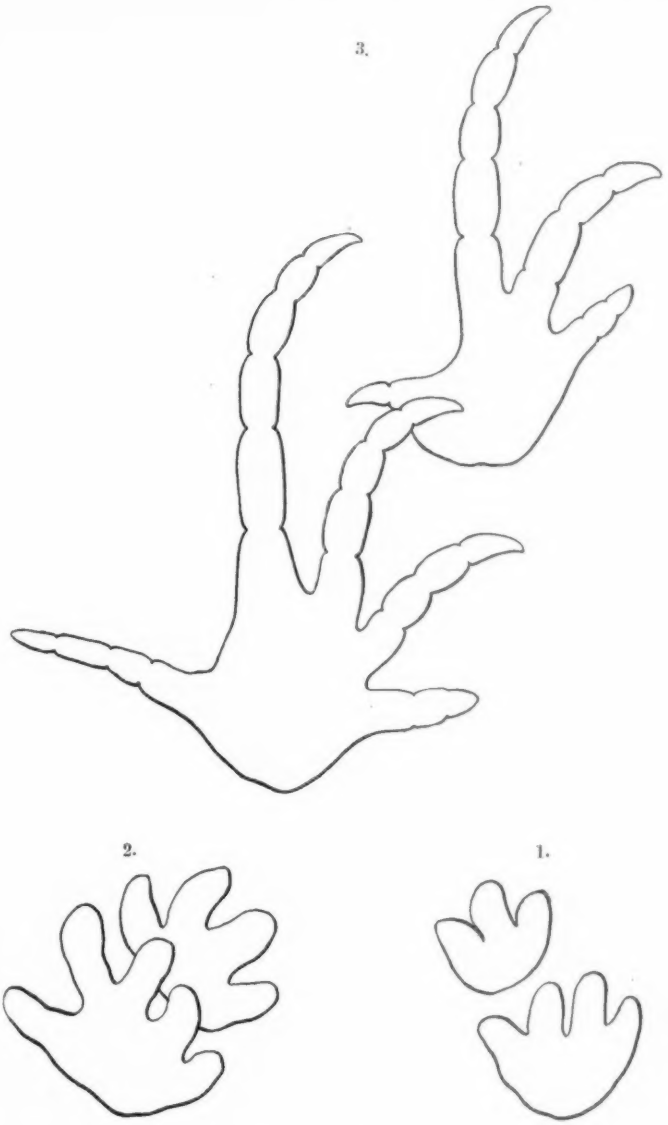
FIGURE 2.—Outline of left fore and hind footprints of *Limnopus vagus*.

FIGURE 3.—Diagram of left fore and hind footprints of *Dromopus agilis*.

All the figures are natural size.



FOOTPRINTS FROM KANSAS COAL MEASURES. One-twelfth natural size.



FOOTPRINTS FROM KANSAS COAL MEASURES. Natural size.

Art. XI.—*The Typical* Ornithopoda *of the American Jurassic;* by O. C. Marsh. (With Plates IV–VII.)

The herbivorous Dinosaurs now known from the Jurassic deposits of this country consist mainly of the gigantic *Sauropoda* and the huge *Stegosauria*, both quadrupedal forms. A third group is the bipedal *Ornithopoda*, which contains the genus *Camptosaurus* as well as various smaller and more bird-like types. The first two groups have been investigated by the writer, and the main results published in this Journal. The third group also received considerable attention during the above investigation, but a recent study both of the type specimens and additional material has revealed new points of interest, and some of these are given in the present article.

Camptosaurus, Marsh, 1885.

The large Dinosaur described by the writer as *Camptosaurus dispar*, of which a restoration also has recently been published,* is now so well known that it may be taken as a form typical of the group. It is exceeded in size by *Camptosaurus amplus*, Marsh, but there are at least two smaller species of the genus (*C. medius* and *C. nanus*, noticed below). So far as at present known, these species are found in successive deposits of the same general horizon, the smallest below and the largest above.

Camptosaurus amplus is represented by remains which show that this reptile when alive was about thirty feet in length. The type specimen of *C. dispar* was about twenty feet in length, and ten feet in height. *C. medius* was about fifteen feet long. The smallest species of the genus, *C. nanus*, was not more than six feet in length, and perhaps four feet in height when standing at rest. One of the striking features of this diminutive species is its long sigmoid scapula shown in figure 3, Plate V. This is in strong contrast with the short, straight scapula of *C. dispar*, seen on the same plate, figure 2. The limb bones of all the species of this genus are very hollow.

* This Journal, vol. xlvii, p. 245, March, 1894. See also, vol. xviii, p. 501, December, 1879; and vol. xxix, p. 169, February, 1885

The skull, brain, and teeth, of *C. medius* are shown on Plate IV. The peculiar peg and notch articulation in the sacral vertebræ of this genus, already described, is indicated on Plate VI, figure 2, and a summary of the principal characters of the genus, and of the nearest allied genera, will be found in the text below.

Dryosaurus, gen. nov.

Another genus of Jurassic Dinosaurs, allied to *Camptosaurus*, but differing from it in many important respects, is *Dryosaurus*, the one here established. The type was described by the writer in 1878, under the name *Laosaurus altus*, and a tooth, the pelvis, and a hind leg, were also figured.* Additional material since received shows that this genus is quite distinct from *Laosaurus*, to which it was at first referred, and is intermediate between *Camptosaurus* and that genus, as is shown in a summary of the characters of these genera given later in the present article.

The European representative of *Dryosaurus* is *Hypsilophodon*, Huxley, from the Wealden of England. That genus, however, differs from the nearest allied forms of this country in several well-marked characters. Among these, the presence of teeth in the premaxillary bones and a well-ossified sternum are features not seen in American Jurassic forms. The fifth digit of the manus, moreover, in *Hypsilophodon* is almost at right angles to the others, and not nearly parallel with them as in *Dryosaurus*. It agrees with the latter genus in having the tibia longer than the femur.

The only species of *Dryosaurus* at present known is the type first described, and in future this may be called *Dryosaurus altus*. Several specimens of this Dinosaur are preserved in the Yale Museum, and they show it to have been in life about twelve feet long, and one of the most slender and graceful members of the group. The known remains are all from the Atlantosaurus beds of Colorado and Wyoming.

Laosaurus, Marsh, 1878.

The present genus includes several species of diminutive Dinosaurs, all much smaller than those above described, and possessing many features now seen only in existing birds, especially in those of the ostrich family. The two species of the genus first described by the writer (*Laosaurus celer*, the type, and *L. gracilis*)† show these avian features best of all,

* This Journal, vol. xvi, p. 415, plate ix, November, 1878.
† *Ibid.*, vol. xv, p. 244, March, 1878.

and it would be difficult to tell many of the isolated remains from those of birds. A larger species, which may be called *Laosaurus consors*, is now known by several skeletons nearly complete. The type specimen, here figured in part on Plates V–VII, is the most perfect of all, and this was collected by the writer in 1879. The animal when alive was about eight or ten feet in length. The known remains are from the Atlantosaurus beds of Wyoming.

One of the distinctive features of this genus, which separates it at once from those above described, is the pubis. The prepubis, or anterior branch of this bone, which was very large and broad in *Camptosaurus*, still long and spatulate in *Dryosaurus*, is here reduced to a pointed process not much larger than in some birds. These differences are shown in Plate VII, figures 1, 2, and 3.

Nanosaurus, Marsh, 1877.

The smallest known Dinosaur, representing the type species of the present genus, was described by the writer in 1877, under the name *Nanosaurus agilis*.* The type specimen consists of the greater portion of the skull and skeleton of one individual, with the bones more or less displaced, and all entombed in a slab of very hard quartzite. The whole skeleton was probably thus preserved in place, but, before its discovery, a part of the slab had been split off and lost. The remaining portion shows on the split surface many important parts of the skeleton, and these have been further exposed by cutting away the matrix, so that the main characters of the animal can be determined with considerable certainty.

A study of these remains shows that the reptile they represent was one of the typical *Ornithopoda*, and one of the most bird-like yet discovered. A dentary bone in fair preservation (Plate VI, figure 3) indicates that the animal was herbivorous, and the single row of pointed and compressed teeth, thirteen in number and small in size, forms a more regular and uniform series than in any other member of the group. The ilium, also, shown on the same plate, is characteristic of the *Ornithopoda*, having a slender, pointed process in front, but one much shorter than in any of the larger forms. The posterior end is also of moderate size. All the bones of the limbs and feet are extremely hollow, strongly resembling in this respect those of birds. The femur was shorter than the tibia. The metatarsals are greatly elongated and very slender, and there were probably but three functional toes in the hind foot.

* This Journal, vol. xiv, p. 254, September, 1877.

A second form referred by the writer to this genus, under the name *Nanosaurus rex*, may perhaps belong to the genus *Laosaurus*. The femur is shown on Plate VI, figure 5. The animal thus represented was considerably larger than the present type species, and from a somewhat higher horizon in the Atlantosaurus beds.

The type specimen here described, which pertained to an animal about half as large as a domestic fowl, was found in Colorado. This reptile was a contemporary of the carnivorous *Hallopus*, likewise one of the most diminutive of Dinosaurs, and one of the most remarkable.

The various Dinosaurs thus briefly referred to under their respective genera have many other points of interest that cannot be here discussed, but their resemblance to Birds is worthy of some notice. This is apparent in all of them, but, in the diminutive forms, the similarity becomes more striking. In all the latter, the tibia is longer than the femur, a strong, avian character, and one seen in Dinosaurs only in the small bird-like forms.* In *Nanosaurus*, nearly all, if not all, the bones preserved might have pertained to a bird, and the teeth are no evidence against this idea. In the absence of feathers, an anatomist could hardly state positively whether this was a bird-like reptile or a reptilian bird.

The main characters of the four genera above discussed are as follows:—

Camptosaurus.

Premaxillaries edentulous, with horny beak. Teeth large, irregular, and few in number. A supra-orbital fossa. Cervical vertebræ long and opisthocœlous. Lumbars present. Five free vertebræ in sacrum, with peg and notch articulation. Limb bones hollow. Fore limbs small. Sternum unossified. Five functional digits in manus. Prepubis long and broad; postpubis elongated. Femur longer than tibia. Metatarsals short. Three functional digits in pes; the first rudimentary, and the fifth wanting.

Dryosaurus.

Premaxillaries edentulous, with horny beak. Teeth of moderate size. A supra-orbital fossa. Cervicals long and biconcave. No lumbars. Six coössified vertebræ in sacrum, without peg and notch articulation. Limb bones hollow. Fore limbs very small. Sternum unossified. Five digits in manus. Prepubis long and narrow; postpubis elongate and slender. Posterior limbs very long. Femur shorter than tibia. Metatarsals long and hollow. First digit in pes complete; fifth metatarsal represented by short splint only.

* Besides the genera here mentioned, *Cœlurus*, *Compsognathus*, and *Hallopus* also possess this character.

Laosaurus.

Premaxillaries edentulous. Teeth small and irregular. Cervicals short and flat. Six vertebræ in sacrum; no peg and notch articulation. Sternum unossified. Fore limbs small. Limb and foot bones hollow. Prepubis very short and pointed; postpubis slender. Femur shorter than tibia. Metatarsals elongate. First digit in pes functional; fifth rudimentary.

Nanosaurus.

Teeth compressed and pointed, and in a single uniform row. Cervical and dorsal vertebræ short and biconcave. Sacral vertebræ three (?). Anterior caudals short. Ilium with very short, pointed front, and narrow posterior end. Fore limbs of moderate size. Limb bones and others very hollow. Femur curved and shorter than tibia. Fibula pointed below. Metatarsals very long and slender.

The genera thus defined contain all the known forms of the the typical *Ornithopoda* from the American Jurassic. They are, moreover, the earliest representatives of this group known in this country from osseous remains, as such fossils have not yet been found in the Triassic, where the oldest Dinosaurs occur. Some of the bird-like footprints in the Connecticut river sandstone may indeed have been made by Dinosaurs of this group, but there is no positive evidence on this point. The American Cretaceous forms of the typical *Ornithopoda*, so far as at present known, are all of large size, and highly specialized, and this appears to be true, also, of the Old World species.

In considering the relations of this well-marked group, here called the typical *Ornithopoda*, with the other two nearest allied suborders, the quadrupedal *Stegosauria* and *Ceratopsia*, it becomes evident, as previously shown by the writer, that all three belong in one great group, which may be regarded as an order. Although differing widely from each other in many notable features, they have a few characters in common, which are important enough to bind them together, and perhaps to indicate a common origin. The most significant of the characters shared by all is the predentary bone, which no other vertebrates possess. Another common character of importance, although sometimes nearly obsolete, is a postpubic bone which is present in all Birds, although in some recent forms it is rudimentary. A comparative series showing the relative development of the anterior and posterior branches of the pubis in six genera of American Predentate Dinosaurs is shown in Plate VII.

In recognition of the manifest relations of the three groups, *Ornithopoda* as here restricted, *Stegosauria*, and *Ceratopsia*, sharply defined as suborders, they should be placed together in a single order, which may appropriately be named the PREDENTATA. This order should be regarded as of equal rank with the *Sauropoda*, the *Theropoda*, and perhaps also the *Hallopoda*, as defined by the writer, the whole constituting the subclass known as the *Dinosauria*.

Yale University Museum, New Haven, Conn., June 15, 1894.

EXPLANATION OF PLATES.

PLATE IV.

FIGURE 1.—Skull of *Camptosaurus medius*, Marsh; seen from the left side.

FIGURE 2.—The same skull, with brain-cast in position; seen from above. Both figures are one-fourth natural size.

FIGURE 3.—Tenth upper tooth of *Camptosaurus medius*.

FIGURE 4.—Fifth lower tooth of same species. Both figures are natural size. *a*, outer view; *b*, posterior end view; *c*, inner view.

PLATE V.

FIGURE 1.—Pelvis of *Camptosaurus dispar*, Marsh; seen from the left. One-twelfth natural size.

FIGURE 2.—Left fore leg of same species. One-twelfth natural size.

FIGURE 3.—Left fore leg of *Camptosaurus nanus*, Marsh. One-fourth natural size.

FIGURE 4.—Left hind leg of *Laosaurus consors*, Marsh. One-sixth natural size.

PLATE VI.

FIGURE 1.—Lower tooth of *Laosaurus consors*. Natural size. *a*, outer view; *b*, posterior end view; *c*, inner view.

FIGURE 2.—Posterior sacral vertebræ of *Camptosaurus dispar*; showing peg and notch articulation; top view. One-fourth natural size.

FIGURE 3.—Dentary bone of *Nanosaurus agilis*, Marsh; seen from the left.

FIGURE 4.—Ilium of same individual; left side. Both figures are natural size.

FIGURE 5.—Left femur of *Nanosaurus rex*, Marsh. One-half natural size. *a*, front view; *b*, side view; *c*, back view; *d*, proximal end; *e*, distal end.

PLATE VII.

FIGURE 1.—Left pubis of *Laosaurus consors*; outer view. One-fourth natural size.

FIGURE 2.—The same bone of *Dryosaurus altus*, Marsh. One-eighth natural size.

FIGURE 3.—The same of *Camptosaurus dispar*. One-twelfth natural size.

FIGURE 4.—The same of *Triceratops prorsus*, Marsh. One-twentieth natural size.

FIGURE 5.—The same of *Claosaurus annectens*, Marsh. One-sixteenth natural size.

FIGURE 6.—The same of *Stegosaurus ungulatus*, Marsh. One-twelfth natural size. *p*, prepubis; *p'*, postpubis.

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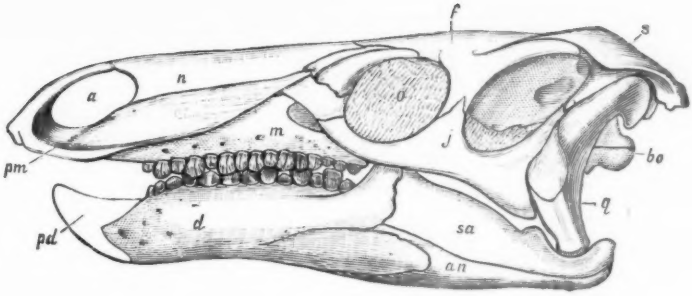

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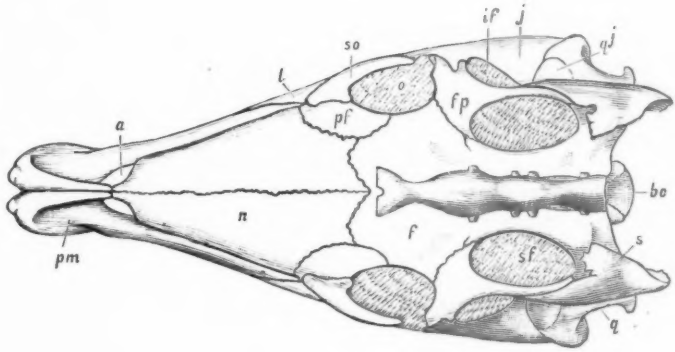

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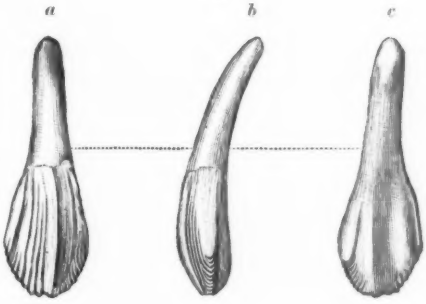

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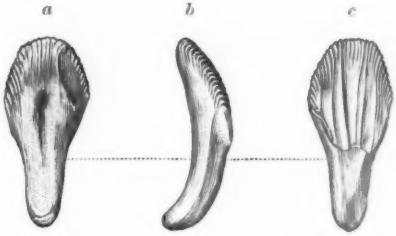
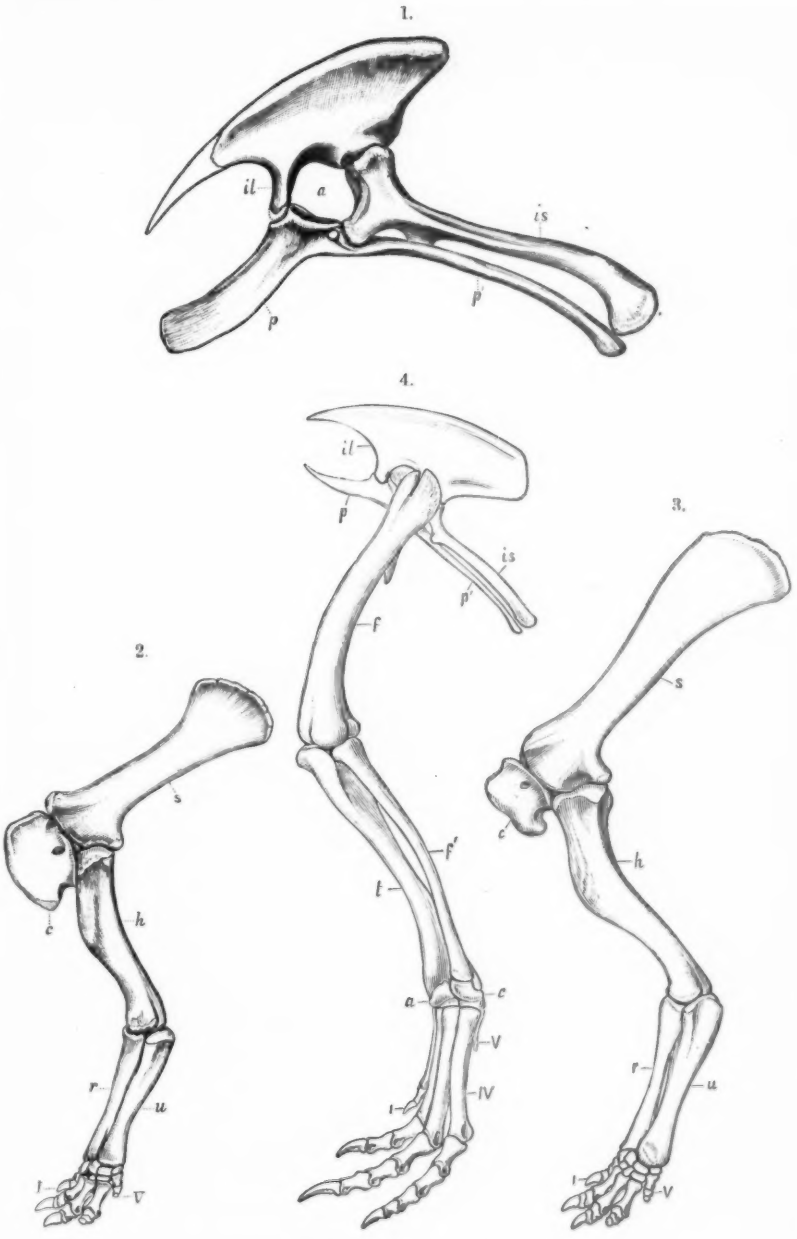
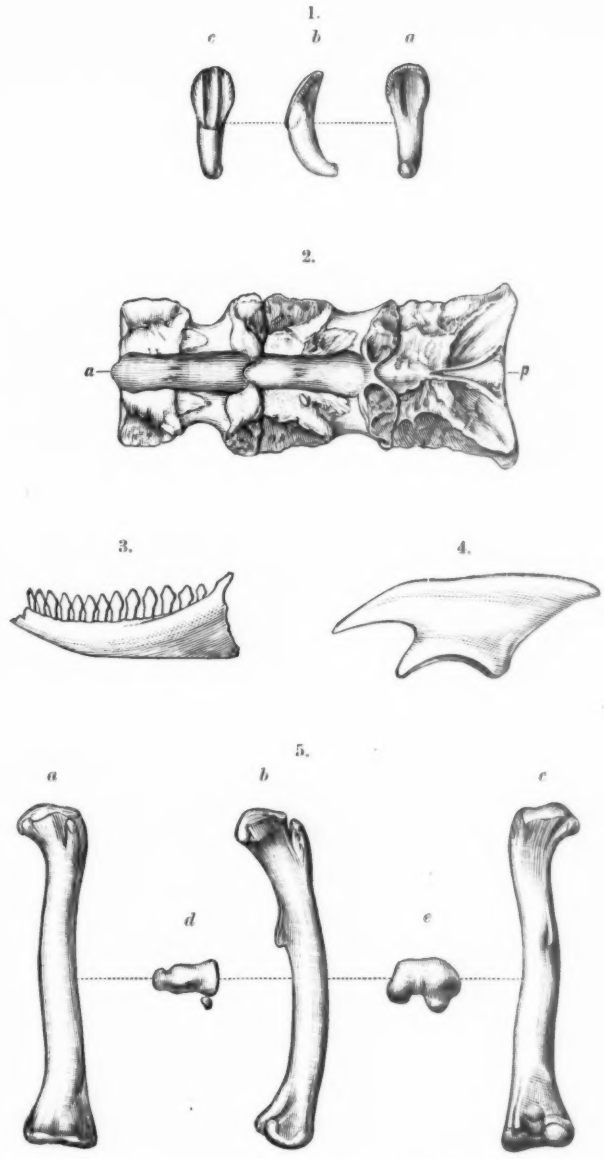


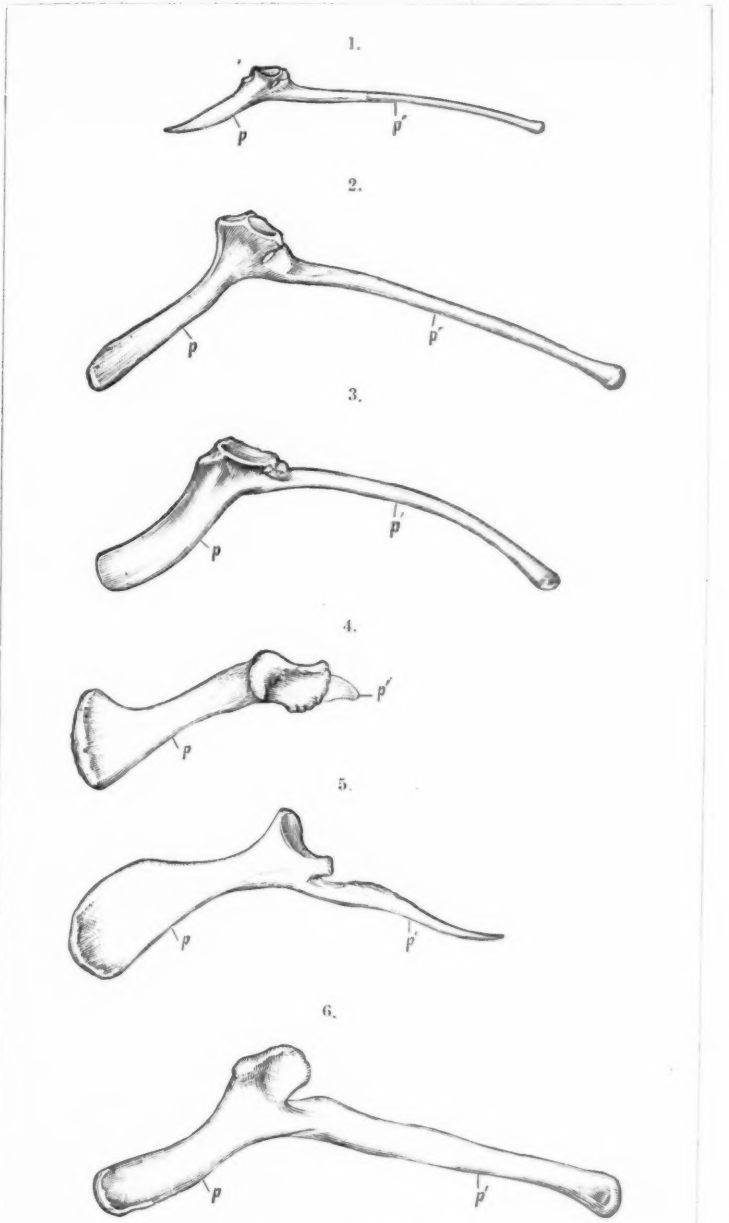
SKULL AND TEETH OF CAMPTOSAURUS MEDIUS, Marsh.



1–3. Camptosaurus. 4. Laosaurus.



1. Laosaurus. 2. Camptosaurus. 3-5. Nanosaurus.



PUBES OF PREDENTATE DINOSAURIA.

ART. XII. — *Eastern Division of the Miohippus Beds, with Notes on some of the Characteristic Fossils;* by O. C. MARSH.

IN 1871, the writer explored the Miocene deposits of Oregon, especially along the valley of the John Day river, and these were again examined with more care in 1873. The strata were found to be nearly a mile in thickness, and deposited in a single lake-basin, which was subsequently named the John Day basin, from the river that now drains it.* The upper portion of these Miocene deposits represented a distinct horizon, and was named by the writer the Miohippus beds, from one of the most characteristic genera discovered in it.† Among other unguiate mammals likewise obtained from these strata were *Diceratherium*, a new genus of the *Rhinoceros* family, and *Thinohyus*, a suilline form allied to the existing peccaries. Subsequent researches brought to light other interesting fossils in this horizon, which has since been supposed to be represented only on the Pacific coast.

The Miocene strata on the eastern slope of the Rocky mountains have long been recognized in two distinct horizons, the lower known as the Titanotherium, or Brontotherium, beds, from the huge mammals which they contain, and above these, the Oreodon beds, of which that genus is characteristic.

Various vertebrate fossils have been obtained from time to time in the eastern Miocene deposits, which were not known to occur in either of the two horizons, but only of late have the uppermost strata been recognized as distinct from the Oreodon beds on which they rest. The horizon thus indicated has been named by Wortman the Protoceras beds, from a most remarkable genus, *Protoceras*, recently found in them, and described by the writer.‡

An examination of material from this horizon, recently made by the writer, brought out the interesting fact, that the genus *Miohippus* is one of its characteristic fossils, and that the type species, *M. annectens*, Marsh, described in 1874 from the Oregon beds, is present. *Diceratherium*, *Thinohyus*, and other genera typical of the western strata, are also found in the eastern, so that it is now demonstrated that the Miohippus horizon has an eastern as well as a western division, a fact of much scientific interest. Doubtless each division will be found to contain certain forms peculiar to itself, even if all are contemporaneous, a question which future discoveries must decide.

* This Journal, vol. ix, p. 52, January, 1875.
† *Ibid.*, vol. xiv, p. 355, November, 1877.
‡ *Ibid.*, vol. xli, p. 81, January, 1891.

The next Tertiary horizon higher up has been regarded by the writer as of Pliocene age, and named the Pliohippus beds, from one of the characteristic equine genera contained in it. This horizon is a very extensive one, and has been identified by the writer at various points along the eastern side of the Rocky mountains, from Canada to the Gulf of Mexico. Essentially the same deposits were likewise found by the writer in 1871 above the Miohippus beds in Oregon. Strata of still later age, named by the writer the Equus beds, occur in the same regions, east and west, often covering the Pliohippus deposits.

Among the fossils of the eastern *Miohippus* beds, the artiodactyle mammals play an important part, and a few of the more interesting of these are noticed in the present article. The *Protoceras* family is of paramount interest, and the specimens in the Yale Museum promise to add considerable to what is now known of this group. The interesting family *Agriochœridæ* also occurs in this horizon.

Another family, the *Anthracotheridæ*, is well represented, and contains some of the largest mammals of the horizon. Two of these, briefly noticed below, are now known only by fragmentary remains, some of which are characteristic. The two figures in the text show respectively a last upper molar of each of these animals. A comparison of these figures indicates that the two animals were quite distinct from each other, although about the same size, and perhaps nearly related.

Octacodon valens, gen. et sp. nov.

The tooth represented natural size in figure 1 below may be regarded as the type of the present genus and species. It is the last upper molar of the right side, and is in fine preservation. The slight wear of the tooth shows that the animal was adult. There are five main cusps in the crown, two on the posterior half, and three on the anterior, the antero-median cusp being the smallest. On the outer margin of the tooth are three prominent buttresses with conical summits, making in all eight prominences on the crown, which feature has suggested the generic name.

The three conical buttresses on the outer border of this tooth, all strongly developed, will serve to distinguish it from the corresponding molar of *Hyopotamus*, which in several respects it resembles. In that genus, the main cusps are much more elevated. *Heptacodon*, perhaps an allied form, has a similar buttress at the anterior angle, but none at the posterior. An upper incisor found with the present tooth, and doubtless pertaining to the same individual, has a very short, compressed crown, with a strong inner basal ridge, making the inner face deeply concave.

Heptacodon armatus, sp. nov.

Figure 2, below, represents natural size the last right upper molar of another large ungulate mammal, the exact affinities of which cannot now be determined. This tooth is considerably worn, showing that it belonged to an old animal. The remaining molars and part of the premolars in the same series are preserved, and with them a very large canine still in position in the jaw. All are worn, but otherwise in good preservation. The tooth figured has a crown composed of five main cusps, the antero-median being the smallest. The outer buttresses are of moderate size, and there is none at the posterior angle. The enamel of this tooth and of all the series is rugose. The true molars differ greatly in size, the first being quite small, the second intermediate, and the last equal in bulk to the two others.

The last premolar has one outer and one inner cusp. The next tooth in front is larger, and has a triangular crown, and the next is close to it. The canine is very large, dependent, and oval in section. Behind it is a long diastema.

1. 2.

FIGURE 1.—Last upper molar of *Octacodon valens*, Marsh; seen from below.
FIGURE 2.—The same tooth of *Heptacodon armatus*, Marsh; seen from below.
Both figures are natural size.

Protoceras comptus, sp. nov.

A second species of this interesting genus is indicated by a young skull from the same horizon in which the type was found. This specimen, apparently the skull of a female, is in good preservation, and, when compared with the type, differs in several essential points. The maxillary plates are not elevated along the sides of the nasal aperture, and the posterior nares extend forward to between the first true molars. The whole skull is proportionally more elongate, and the facial part especially produced.

The maxillary plates of the palate are deeply cleft in front. The anterior palatine foramina open just in front of the second premolars, and long, shallow grooves extend from them to the front of the palate. The nasals are deeply furrowed behind by grooves leading backward to the supra-orbital foramina. The parietal ridges show a rugosity at the points where the horn-cores would later have appeared. The entire length of the skull is about eight inches, and from the front to the end of the molar series is five inches.

Calops cristatus, gen. et sp. nov.

The present type specimen is a skull in fair preservation, indicating a fully adult animal, which when alive was about half as large as a goat. In its general form and in most of its characters, this skull agrees so closely with the type of *Protoceras* as to suggest at once some affinity between the two. The dentition preserved in the premolar and molar series is essentially the same. The high maxillary plates joining the short, pointed nasals; the deep lachrymal fossa; and the posterior orbit strongly closed behind, all suggest an ally of *Protoceras*, but the parietal ridges are here elevated into distinct crests, and are without horns.

This skull when complete was about six inches in length. The distance from the front of the nasals to the junction of the parietal crests is about four inches and a half. The space occupied by the last three premolars and the true molars is about two and one-half inches.

Thinohyus robustus, sp. nov.

A new species of this genus is indicated by a nearly perfect skull, which shows many features of interest. It indicates an animal much larger than the type from Oregon, and one slightly superior in size to the existing collared peccary. In many respects, it resembles the latter so much, that it may be considered one of its direct ancestors.

The present species has the full complement of teeth, forty-four, but the skull has shortened, so that the first upper premolar has been crowded inside the canine. The teeth are proportionately larger than in *Dicotyles*. The last upper molar is smaller than the first or second. The last premolar has two outer cones, and one inside. The space occupied by the three upper molars is one and three-fourths inches, and the extent of the entire dental series is five inches. The whole skull is about nine inches in length.

Yale University Museum, New Haven, Conn., June 22, 1894.

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